The
ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XII No. 9. SEPTEMBER, 1951

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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *RESEARCH ON PLASTICS*

A large research programme on plastics carried out in America has led to the development of a new rapid method for controlling the curing process of plastics in commercial moulding plants. The investigations have also resulted in the discovery that molecular re-orientation will considerably increase the tensile strength of polystyrene. The general aim of this research was to provide data necessary for the development of theories on the behaviour of plastics under stress. In the curing phase of the studies, it has been shown that the transmission and absorption of sound waves through thermosetting resins varies with their degree of cure. Consequently, the rate and extent of curing can be ascertained by measuring the changes in the velocity and intensity of sound waves passed through the plastic while undergoing the process of curing. It is stated that the results obtained indicate the possibility of developing a reliable and accurate rapid test method for commercial application. When investigating the properties of polystyrene, it was found that it is possible to alter the characteristics of polystyrene to a considerable extent by stretching the material while it is still in the hot plastic state. Pieces treated in this way show, after cooling, ultimate strengths in the direction of stretch orientation which approximate to three times the strength of an unstretched specimen. Various methods were tried for measuring the degree of orientation produced by the stretching process, and it was found that stretching produces only a low order of orientation. These findings on the behaviour of polystyrene have already found practical application in the production of flexible sheets.

● *COLD SYNTHETIC RUBBER LATEX*

Reports from America indicate that the development of a cold synthetic rubber latex has been achieved which is claimed to approach natural rubber latex in service and wearing quality. It appears that while many types of synthetic rubber latex have been produced on a laboratory scale, the new cold varieties which have now been placed on the market are the first of the general purpose type which may possibly compete with natural rubber latex in commercial applications on a large scale. As there exists no type of latex which could be considered an all-purpose type, seven distinct varieties of cold rubber latex have been developed, and many more may be introduced in future. It is claimed that special grades of synthetic latex can be prepared to suit specific requirements, which has not so far been possible with the natural product. One variety of cold synthetic latex can be used as complete replacement for the natural product in the manufacture of foam sponge for furniture cushioning, automotive upholstery, and mattresses. Other varieties are stated to show promise as replacement for natural latex in the manufacture of types containing rayon tyre cord, in several dipping processes, and in the manufacture of sheet packing materials and brake linings. The original report contains no information on the relative cost of the synthetic latex as compared with the natural product.

● *SIMPLE CONTROL DEVICE*

There are many cases in industrial process technique in which the employment of automatic controls is considered desirable but cannot be realised because of the disproportionate cost of control equipment required. An American manufacturer of control equipment claims to have filled the gap by the development of an inexpensive type of electric control. The basic element of this gear is a D'Arsonval meter fitted with self-locking contacts, which can be set to make or break contact at any point of the scale. The small force available from the moving system of the meter is obviously incapable of producing the contact pressure required to prevent sparking and, consequently, premature failure of the contacts. The solution to the problem was found to lie in the provision of self-locking action by a very simple means which presses the contacts together once initial contact has been made. For this purpose, the moving element of the instrument is fitted with two coils instead of the one normally used. The one coil is connected to the electrical input to be measured and the second coil is in series with the meter contacts, the load relay coil, manual or automatic reset contacts and a source of power. The polarity of the power supply is such that when the meter pointer moving up the scale closes the contact, the torque created by the current flowing through the second coil adds to that produced by the primary coil. This torque locks the contacts together and the locking current also operates the load relay to produce whatever control action is desired.

Of the 2,500 different species of snakes — the Cobra is the most poisonous. The King Cobra or Hamadryad reaches as much as 16 ft. in length and has a nasty habit of erecting his hood when annoyed. And they don't *sting with their tongues—these are merely for touch and smell. The poison comes from hollow teeth — nice sharp teeth — teeth in fact which are perfectly designed for the job.*

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● *NOVEL CONTACT SYSTEM FOR SWITCHES*

The limited current-carrying capacity of metallic contacts of the type used in switches with contact blades is due to the fact that the actual metallic contact between the contacting surfaces is confined to a small number of points. A considerable increase in current-carrying capacity would result from increasing the number of points of metallic contact to such an extent that a line contact would be approximated. A recent design aims at the realization of a switch with a plurality of such line contacts by employing resilient contacts which grip the blade in pincer-like fashion so that the " biting edges " press upon the blade, without, however, scoring it. In order to increase the resiliency of the pincers, each pincer is twice slit, so that three biting edges bear upon each side of the switch blade. In order to minimise contact resistance, each biting edge is silver-plated. The number of pincer units to be employed is, of course, chosen in accordance with the amperage to be carried. In addition to the pincer units, each switch is provided with special arcing contacts which can be easily replaced. A switch of this type with a current-carrying capacity of 600 amps will be composed of 3 sets of pincer units and one arcing unit having 22 line contacts or biting edges in all. It has been found that with increasing contact metal temperature, the contact resistance actually decreases.

● *SUPERSENSITIVE THERMO-ELEMENT OF NYLON*

Thermo-sensitive elements made from bi-films of polymers with selected orientation exhibit some tenfold greater motion per degree change of temperature than any known metallic thermo-element. This recent development is based on the fact that certain plastics such as nylon, polythene, saran, etc., can be permanently oriented by mechanical stretching so that the chain-like molecules are made to lie more or less parallel to the axis of pull. When heated, these molecular chains contract and thereby cause the material as a whole to have a negative coefficient of thermal expansion along the direction of orientation. These same polymers when unoriented have large and positive rates of thermal expansion. Consequently, a thermo-element formed from an oriented specimen and an unoriented specimen of a given polymer displays an unusually large rate of " curl " per degree. For most bimetallic combinations, the difference in coefficients of thermal expansion is about 3×10^{-5} units, but for a combination of highly oriented and unoriented nylon, the difference is 3×10^{-4} units. Large thermo-mechanical responses may also be obtained with films and fibres of polyethylene and polyhydroxyl alkane resins and other polymers. By the proper choice of polymer and construction, minimum sensitivity to moisture changes can be obtained. It is suggested that these simple thermo-elements could be used for ultra-sensitive research instruments, inexpensive thermometers, thermo-regulators, etc., and also for thermo-switches after coating the films with a conductive layer. These thermo-elements cannot, however, be used for temperatures exceeding 150-180° C.

● *SPECTROMETERS FOR AUTOMATIC ALLOY ANALYSIS*

Direct-reading spectrometers are now available which give complete and accurate analyses of brass and bronze alloys in a few minutes. When using the instrument, the alloy sample is sparked and the light from a single selected spectral line cast by each element is converted from light energy into electrical energy by means of electronic tubes. The electronic circuit energises an electrical recording instrument which registers the percentage of each element present in the sample examined. It is claimed that in a modern instrument of this type, as many as eight elements present in the alloy, even in minute quantities as small as 0·002 per cent, can be accurately analysed in as short a time as two minutes. Considering the speed and accuracy achieved with instruments of this type, they should prove valuable in freeing metallurgists engaged in routine analyses for more important tasks. Unfortunately, however, instruments of this kind are of considerable complexity, and apart from any maintenance difficulties that may possibly arise, their high initial cost may prove a major drawback.

● *NOVEL GRADIENT TANK FOR AIRCRAFT RESEARCH*

It is known that certain aerodynamic problems in aircraft research can be solved more conveniently by using an electrolytic gradient tank than by the use of the conventional wind tunnel. In the gradient tank, the air current of the wind tunnel is replaced by an electric current flowing between parallel metal electrode plates immersed in the tank, which is filled with an electrolyte. If an aircraft model made of electrically insulating material is immersed in the tank, between the electrodes, the electrical field strength distribution will reproduce the air velocity distribution around the actual aircraft, assuming frictionless and incompressible air flow. The usual technique employed heretofore has been of the indirect type, in which the electrical field strength distribution and with it the velocity distribution were derived from the measurement of the electrical potential distribution in the electrolyte. A novel, more accurate, method consists in effecting the direct measurement of the electrical field by means of an unbalance method employing an auxiliary gradient tank also equipped with electrodes. In a typical installation of this type, both tanks are filled with ordinary tap water and the electrodes are con-

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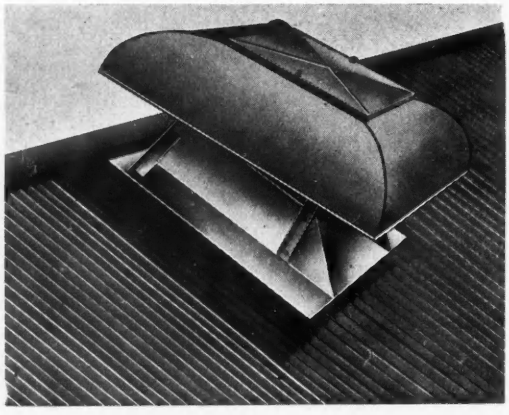

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nected with a 25-volt alternating current supply at 437 cps. Each tank is equipped with its individual measuring electrode and these are connected with a bridge-type circuit. Initial balance is established by calibration when both electrodes are at corresponding spots in the two tanks. By immersing the model in the main tank, the field distribution, and with it the electrical balance, are upset and can be restored by displacing the electrode in the auxiliary tank. The displacement required will then be a measure of the air velocity and direction at the spot investigated.

● *REINFORCED STEEL TUBING*

Among the very great number of uses of steel tubing as a structural material, there are many cases in which the thickness of the tubing is solely governed by aspects of buckling strength. Considerable savings in material—and this would be of especial importance in these days of growing steel shortage—could therefore be achieved if it were possible to effect an increase in buckling strength in a simple yet inexpensive way. The ingenious proposal has been made by a Continental inventor to take a cue from nature, which has endowed the woody stem of bamboo grass with an extraordinary degree of strength by providing internal nodes at what, to all appearances, are optimum intervals. By what is claimed to be an extremely simple process, steel tubes are fitted with internal diaphragms at appropriate distances, thus creating a structure aptly described as "steel-bamboo" tubing. The process is stated to require no special machinery of any kind and to permit of inexpensive mass production. It is reported that steel tubing of this type has already been successfully used for the lamp standards installed in the street of a Continental town. Other obvious possible applications are masts for the overhead wires of electric trolleybus systems and electric railway lines. By replacing pylons of high-tension transmission lines, which are now made of angular members, by novel-type pylons of the new tubular material, the saving in weight achieved is as high as 50 per cent, it is claimed. It would appear that the process well deserves close study both from the technical and economic aspects.

● *NOVEL HARDENING COMPOUND*

It is reported that a fast-acting casehardening compound has been developed, which is claimed to combine the advantages of carburizing, nitriding and chromizing. A particularly interesting feature is that the entire treatment takes only a few minutes, the part to be treated being heated and coated with a paste or powder, the coating being fused for a few seconds and the part being quenched. The process can be used to impart high hardness and abrasion resistance to the surface of low carbon steel. No special production heating equipment is needed, an open forge, a gas and oxygen torch, or an acetylene torch being sufficient in most cases. Where available, an electric furnace or an induction coil can also be used. The new compound is not designed to replace the conventional pack carburizing or nitriding, where a considerable depth of case is needed over large surfaces. However, it appears to be useful where repairs have to be carried out or where parts have to be selectively hardened. Nor is the chromium impregnation effected a real chromizing process. The compound contains special activating agents which speed up the impregnating process and allow sufficient carbon to enter the steel surface within the few seconds the coating is being fused on to the hot piece, so as to give hardness on quenching. In addition to the carburizing constituents, the compound contains ammonium compounds which produce a nitriding effect and complement the hardening action of carburizing. The case produced is relatively thin and ranges from 0·0004 to 0·0006 inch after one application.

● *CERAMIC COATINGS FOR AERO-ENGINE EXHAUST SYSTEMS*

A recent investigation of the corrosive effects of lead bromide vapours contained in the exhaust of aero-engines upon various heat-resistant alloys, both with and without protective ceramic coatings, has yielded important information. The uncoated alloys were found to corrode rapidly when exposed to such vapours at high temperatures, while the application of ceramic coatings effectively prevented corrosion under identical conditions. The lead bromide present in the exhaust gases, of course, has its origin in the chemical interaction of tetraethyl lead and ethylene dibromide, which are the active additives contained in leaded aviation spirit. The ethylene dibromide converts the lead oxide which would otherwise form during the combustion process into lead bromide. The latter has a considerably higher vapour pressure than lead oxide, and for this reason it is more readily passed through the exhaust system in the vapour phase. The heat-resisting alloys tested included Inconel, two stainless steels, vitallium, and another turbine blade alloy. Only the first three alloys are normally employed for aircraft exhaust systems, as the last two alloys are too expensive for this purpose, but it was felt that they might be used for small critical parts. Each alloy was studied with three different ceramic coatings, and a pre-oxidised specimen was also investigated, in addition to one specimen in unprotected state. All uncoated alloys were found to suffer severe corrosion, the stainless steels giving the poorest results owing to a selective attack which produced a spongy layer near the surface. Pre-oxidation of the surfaces retarded corrosion only for the first hour or two of the test. No consistent relation between temperature and rate of corrosion was found.

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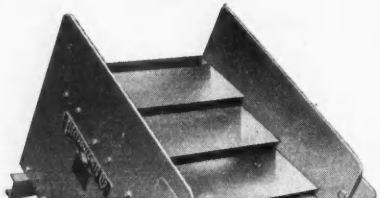

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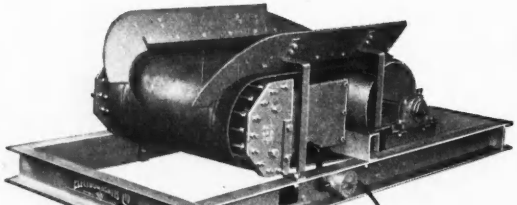

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● *PRODUCTION OF CLAD TUBING BY PILGER PROCESS*

The present shortage of nickel supplies lends additional importance to the various methods available for cladding mild steel with thin corrosion-resisting layers of nickel-chromium alloys. A number of processes has been evolved in which an intimate bond between the protective layer and the parent metal can be secured. Especially interesting problems exist in the case of seamless drawn tubular products, in which the protective cover may be provided either inside or outside or on both the inside and outside of the tube. Aspects of tube manufacture require that the cladding process should be carried out at an early stage of the manufacturing process, and in cases where seamless tubing is produced by the Pilger process, the cladding must therefore precede the latter. In view of the large stresses and deformations produced in the Pilger rolling process, it is, of course, of the greatest importance that a perfect bond be ensured between the two materials involved. In this respect, conditions are particularly severe in cases where the cladding material forms an external layer, as this layer is subject to by far the greatest deformations occurring in the Pilger process. It goes without saying that the production of thin cladding entails additional problems. Internal cladding is carried out by boring the billet and then inserting an accurately fitting tube of the cladding material. The face edges of the two materials at the ends of the billet are then carefully sealed by welding in order to prevent atmospheric oxygen from entering the gap between the two materials during heating up to rolling temperature. The quality of bond that can be obtained in this process can be gauged from the fact that stainless-clad tubes successfully withstood 20 heatings to 1,000°C and subsequent quenching in water without any deterioration of the bond.

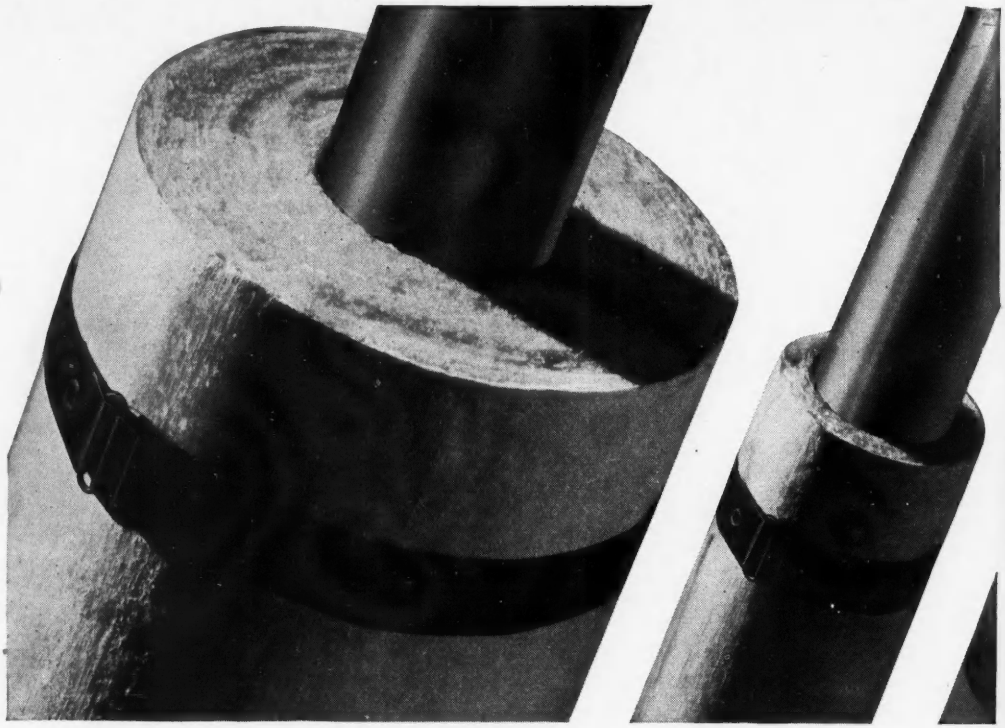
● *CAST BASALT AS SUBSTITUTE FOR CAST IRON*

Considering the fact that rocks are the solid product of igneous matter which originally existed as liquid lava, and that slag produced in metallurgical processes has been utilized for casting shaped articles, such as paving stones, etc., it is surprising that rock as such has never been utilized as raw material for founding. In searching for substitute materials during the last war, considerable efforts were made in Germany to utilise basalt and diabase as the raw materials for castings. Except for occasional propaganda announcements to the effect that the casting of pipes suitable for high steam temperatures had been successfully achieved by German engineers, very little tangible information became available at the time. It is therefore of considerable interest to note that the casting of basalt and diabase appears now to have been taken up on a commercial scale in Poland and Czechoslovakia. Working of the process is carried out with the use of special furnaces, in which the rock is melted at approximately 1500°C and then poured into the moulds, which may be of sand or iron. The process therefore resembles that employed in an ordinary cast iron foundry. Cooling time is usually 24 hours, but its exact length must obviously depend upon the size of the casting. It is claimed that basalt and diabase castings are in no way inferior to iron castings. An additional advantage is that the cast stone material is electrially non-conductive and resistant to corrosion. The chief products at present are said to be drain pipes, water pipes, tubs of various descriptions, fittings, and other pipe line accessories for chemical industries, etc. Slabs to serve as base plates for machinery are also being manufactured. Basalt quarry waste is used as the raw material.

● *IMPROVED ELECTROSTATIC PAINT SPRAYING PROCESS*

An important improvement in the electro spray process for applying lacquers, enamels, and varnishes to metal parts consists in effecting electrostatic atomization of the coating material before it is discharged from the spray head. This is, of course, a radical departure from the former method of electrospraying, in which air atomization was employed and the atomized paint particles were given a high-potential electric charge as they travelled from the spray gun to the part to be coated. The new type of spray gun used for this process incorporates a hollow cone-shaped spray head. The coating medium is metered at a constant rate to the apex of the head, and as the head is rotated mechanically, the material spreads uniformly over the inner surface of the head by centrifugal action, causing an even flow to the outer edge. A source of high electrostatic potential, having one terminal earthed and the other connected to the head, creates a strong electrostatic field between the head and the part to be painted, which is also earthed. The force of the electrostatic field transforms the liquid coating into a spray of fine, charged particles, and creates an attraction which pulls the particles to the surface of the piece to be coated. The influence of such variable factors as pressure of the atomizing air, spray pattern, fluid delivery and overspray exhaust currents is thus effectively eliminated. No spray booth is therefore needed. The elimination of overspray is claimed to result in an important reduction in paint consumption; in a typical case, paint cost was reduced by 25 per cent as compared with the old process.

For further information on developments reviewed in THE BLUE PAGES, readers are invited to write to the Editor.



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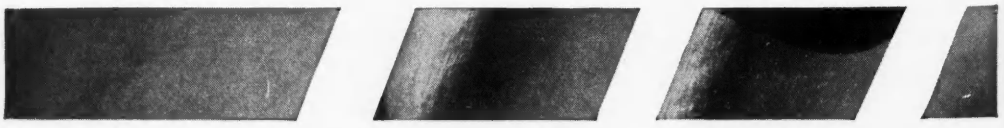

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The "Tuning Curves" Method for the Study of Torsional Vibration Frequencies

By L. TRABUCCO. (From *Bollettino Tecnico FIAT, Italy*, No. 1, 1951, pp. 1-15, 6 illustrations.)

This article describes a modern method for determining torsional vibration frequencies, which has already been used, particularly in connection with aircraft engines. The method is claimed to be simple and gives remarkably accurate results. After describing the theory of the method, an illustrative example is given of the study of various possible arrangements for a large-power marine propulsion engine.

FOR a freely vibrating n-mass system, the equations of motion can be reduced to a simple equation which states that the sum of the inertia torques of the system should be equal to zero at any instant. Therefore, the equilibrium condition can be written as follows :—

$$\sum_{i=1}^{i=n} T_i = 0 \text{ or } \sum_{i=1}^{i=n} \mathcal{J}_i \theta_i \omega^2 = 0 \quad .. \quad (1)$$

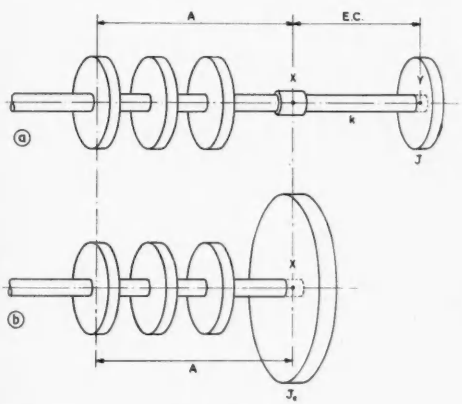
In these expressions, T_i = inertia torque [kg cm], $\mathcal{J}_i$ = polar mass moment of inertia [kg cm sec^2] and θ_i = amplitude of vibration [rad] of the i-th mass, and ω = phase velocity [rad/sec] corresponding to the natural frequency of the system : $f = 60\omega/(2\pi)$.

Furthermore, the twist of the shaft portion between two consecutive masses $\mathcal{J}_{i-1}$ and $\mathcal{J}_i$ is given by

$$\theta_{i-1} - \theta_i = \left(\sum_1^{i-1} \mathcal{J}_i \theta_i \omega^2\right) \Big/ k_{i-1} = \left(\sum_1^{i-1} T_i\right) \Big/ k_{i-1}$$

where k_{i-1} = torsional rigidity [kgcm/rad] of shaft portion connecting the masses $\mathcal{J}_{i-1}$ and $\mathcal{J}_i$. Therefore, the relation between the twist amplitudes of two consecutive masses is

$$\theta_i = \theta_{i-1} - \left\{ \left(\sum_1^{i-1} \mathcal{J}_i \theta_i \omega^2 \right) \Big/ k_{i-1} \right\} \quad .. \quad (2)$$



Figs. 1a and 1b.

(a) **Original system.**
(A = basic system ; $E.C.$ = elastically connected portion).
(b) **Equivalent system.**
$\mathcal{J}_e$ = equivalent mass.

Equations (1) and (2) can be satisfied in two ways :—

(a) When all the $\mathcal{J}$'s and k's have fixed, prescribed values, by finding a well determined set of values for the ω^2 ; or
(b) When all the ω^2's have fixed values, by determining suitable values for either one $\mathcal{J}$- or one K- element for each of the prescribed frequencies.

The " tuning curves method " is the application of the principles derived from the possibilities of (b). In order to obtain any given value of ω^2, a suitable value is chosen for the moment of inertia of one of the masses of the system. The system is, thus, " tuned " to a given vibration frequency.

For simplicity, it can be assumed that the " tuning inertia " is situated at one of the two ends of the system. Equation (1) then gives the value of the " tuning inertia " $\mathcal{J}_s$ as

$$\mathcal{J}_s = \mathcal{J}_n = -\left\{ \sum_{i=1}^{i=n-1} \mathcal{J}_i \theta_i \omega^2 \right\} \Big/ (\omega^2 \theta_n) \; .. \; (3)$$

The " tuning curve " of the system is the diagram of $\mathcal{J}_s$ plotted against the frequency $f = (60/2\pi)\,\omega = 9{\cdot}55\omega$.

DEFINITION OF THE " EQUIVALENT MASS "

Referring to Fig. 1, consider a rotating system A (" main " or " basic " system) capable of vibrating in torsion under forced vibration conditions produced by an externally applied torque. At a point X along its shafting, this main system is coupled to a mass with a moment of inertia $\mathcal{J}$, by means of a shaft of stiffness k.

It can easily be shown that the mass $\mathcal{J}$ can be replaced by an " equivalent mass " $\mathcal{J}_e$ situated at the point X, that is, rigidly connected to the main system. Thus, the auxiliary system of k and $\mathcal{J}$ can be replaced by a single mass $\mathcal{J}_e$ at X. The value of $\mathcal{J}_e$ depends on the original k and $\mathcal{J}$ values and is also a function of the forced vibration frequency f to which the system is subjected.

Let $f_c = 9{\cdot}55\sqrt{k/\mathcal{J}}$ = natural frequency [vpm] of the elastically connected portion, f = forced frequency of the entire system, θ_y = vibration amplitude of mass $\mathcal{J}$ [rad], and θ_x = amplitude at the point X where the main system is coupled to the elastically connected portion.

The torque at X, due to the vibration of $\mathcal{J}$ with a phase velocity $\omega = f/9{\cdot}55$ and a vibration amplitude θ_y, is

$$T_1 = \mathcal{J}\,\omega^2\,\theta_y \quad \text{[kgcm]}$$

The torque at X, due to the vibration of $\mathcal{J}_e$ with an amplitude θ_x, is

$$T_2 = \mathcal{J}_e\,\omega^2\,\theta_x \quad \text{[kgcm]}$$

In order that $\mathcal{J}_e$ may have the same effect as $\mathcal{J}$ on the torsional vibration characteristics of the entire system, the inertia torques must be equal :

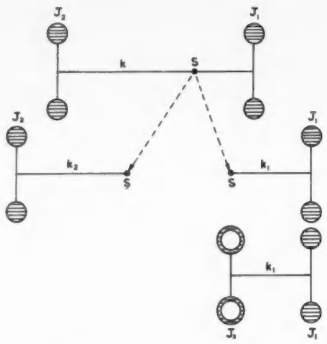


Fig. 2. **Two-mass system**

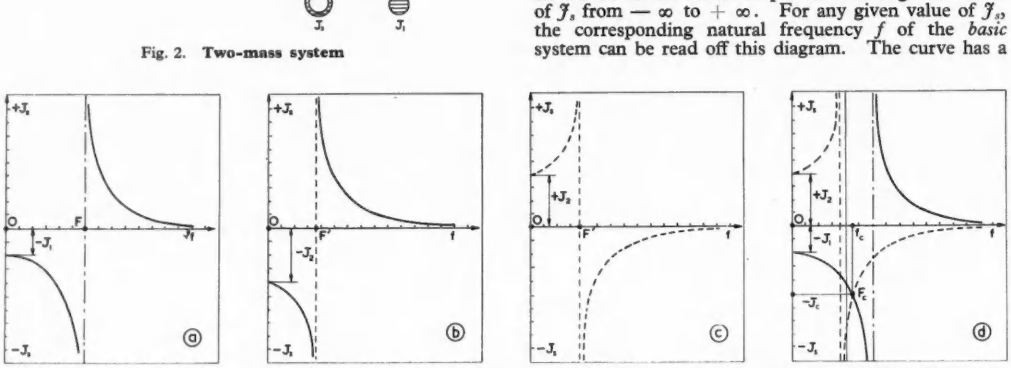
connected portion." This portion can be replaced by an equivalent mass $\mathcal{J}_s$ at the point of division S, so that $k_2 = \infty$. Then, $\mathcal{J}_s$ represents the "effective inertia" of the elastically-connected portion.

The natural frequency of the entire system can be determined from the characteristics of the two sub-systems, which are determined separately and then superimposed in a manner which will be explained in the following lines.

Tuning curve of the basic system : As previously stated, it is assumed that a fictitious mass $\mathcal{J}_s$ is situated at S. For a two-mass system, its value is given by

$$\mathcal{J}_s = \mathcal{J}_1/[(\mathcal{J}_1\,\omega^2/k_1) - 1] \quad .. \quad (6)$$

The "tuning curve" of $\mathcal{J}_s$ plotted against $f = 9{\cdot}55\omega$ should be calculated for all positive and negative values of $\mathcal{J}_s$ from $-\infty$ to $+\infty$. For any given value of $\mathcal{J}_s$, the corresponding natural frequency f of the *basic* system can be read off this diagram. The curve has a



Figs. 2a-2d. (a) **Tuning curve of basic system.** (b) **Tuning curve of elastically connected portion.** (c) **Effective-inertia curve of elastically connected portion.** (d) **Resulting tuning diagram, obtained by superimposing curves** (a) **and** (c).

$$T_1 = T_2 \quad \text{or} \quad \mathcal{J}\,\omega^2\,\theta_y = \mathcal{J}_e\,\omega^2\,\theta_x$$

so that $$\mathcal{J}_e = \mathcal{J}\,\theta_y/\theta_x.$$

If the stiffness k of the shaft connected with $\mathcal{J}$ were infinite, i.e., if $\mathcal{J}$ were rigidly coupled to the main system, we would have : $\theta_y = \theta_x$, or $\mathcal{J}_e = \mathcal{J}$.

However, if k has a finite value, we know from the general theory that, for every finite value of k, we have $\theta_y = M\,\theta_x$, where $M = 1/[1 - (\omega/\omega_c)^2]$ = dynamic magnifier factor for systems in which damping is neglected. Therefore,

$$\theta_y = \theta_x/[1 - (\omega/\omega_c)^2]$$

Similarly, we obtain

$$\mathcal{J}_e = \mathcal{J}/[1 - (\omega/\omega_c)^2] \quad .. \quad .. \quad (4)$$

and since $\omega_c^2 = k/\mathcal{J}$ and $\omega^2 = f^2/91{\cdot}2$ the expression for $\mathcal{J}_e$ becomes

$$\mathcal{J}_e = \mathcal{J}/[1 - (f^2\,\mathcal{J}/91{\cdot}2\,k)] \quad .. \quad (5)$$

This equation confirms that it is possible to replace the elastically connected mass $\mathcal{J}$ by an equivalent mass $\mathcal{J}_e$ which is rigidly attached to the main system. The torsional characteristics of the entire system are unchanged, but the value of $\mathcal{J}_e$ instead of being a constant quantity will vary with the forced frequency of vibration.

TUNING CURVE AND EFFECTIVE INERTIA CURVE

Division into sub-systems : For simplicity, a two-mass system (Fig. 2) will be considered, with two masses $\mathcal{J}_1$ and $\mathcal{J}_2$ connected by a shaft of stiffness k.

By regarding any arbitrary point S along the shaft as a separation point, the system can be subdivided into two sub-systems. The mass $\mathcal{J}_1$ and the shaft portion with a stiffness k_1, ahead of point S, will constitute the "basic system", $\mathcal{J}_2$ and k_2 being the "elastically vertical asymptote at $f = 9{\cdot}55\,k_1/\mathcal{J}_1$, which is the natural frequency of the basic system (see Fig. 2a).

In fact, the natural frequency of the basic system is obtained when $\mathcal{J}_s$ becomes an infinite mass, S then being a fixed point with zero vibration amplitude. As the value of $\mathcal{J}_s$ is reduced, the frequency increases. The curve is also plotted for negative values of $\mathcal{J}_s$. Although these have no physical significance, they may correspond to effects which are obtained when masses are not rigidly attached, as for instance in the case of pendulum dampers.

Effective inertia curve of the elastically-connected system : The next step is to calculate the tuning curve for the elastically connected system. The "tuning inertia" $\mathcal{J}_s'$ for this portion is determined from

$$\mathcal{J}_s' = \mathcal{J}_2/[(\mathcal{J}_2\,\omega^2/k_2) - 1] \quad .. \quad (6')$$

and plotted against the forced frequency f.

Now, if T_s' = vibratory torque exerted at S by the basic system acting on the elastically connected portion, and θ_s' = vibration amplitude of the elastically connected portion at the point S, we have : $T_s' = \mathcal{J}_s'\,\theta_s'\,\omega^2$.

Furthermore, if $\mathcal{J}_s$ = equivalent inertia of the elastically connected portion at S, T_s = vibratory torque due to this portion and acting at S on the basic system, and θ_s = vibration amplitude of the basic system at the point of division S, we may write : $T_s = \mathcal{J}_s\,\theta_s\,\omega^2$.

Then $T_s = -T_s'$ and $\theta_s = \theta_s'$, so that

$$\mathcal{J}_s\,\theta_s\,\omega^2 = -\mathcal{J}_s'\,\theta_s'\,\omega^2, \text{ or}$$

$$\mathcal{J}_s = -\mathcal{J}_s' \quad .. \quad .. \quad (7)$$

The fundamental importance of this equation is that it shows that the "effective inertia" $\mathcal{J}_s$ of the elastically connected portion is the mirror-image of the tuning curve $\mathcal{J}_s'$ of this sub-system relatively to the frequency axis. Thus the effective inertia curves of Fig. 2c are

the tuning curves of Fig. 2b reversed relatively to the horizontal axis representing frequency.

Tuning curve and natural frequency of the entire system : Fig. 2c gives the effective inertia at S of the elastically-connected portion, as a function of frequency. Fig. 2a, being the tuning curve of the basic system, indicates the tuning inertia required at S to obtain a given frequency. There will be, therefore, a certain frequency value F_c for which the effective inertia of one sub-system will be that required by the other to vibrate at this same frequency. This is, then, the natural frequency of the entire system.

The value of F_c is determined graphically by superimposing the tuning curve (Fig. 2a) of the basic system on the effective-inertia curve (Fig. 2c) of the elastically-connected portion. In the resultant diagram (Fig. 2d), the point of intersection of these curves corresponds to the natural frequency f_c, on the abscissae axis, for which both parts of the system are tuned together. The two-mass system has only one natural frequency, since it has one degree of freedom.

THREE-MASS SYSTEM

In the above case, the point of division was situated on the shaft at a position where there was no concentrated mass. However, in a system consisting of three or more masses, it would be possible to situate this point at the position of an intermediate mass, for instance, at $\mathcal{J}_2$ in the case of the three-mass system of Fig. 3.

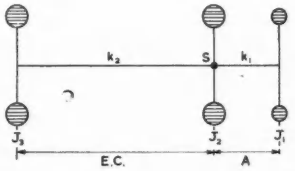
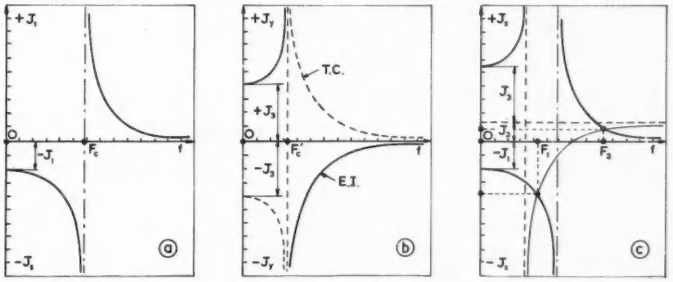


Fig. 3. **Equivalent three-mass system.** S = point of division ; A = basic system ; $E.C.$ = elastically connected portion.



Figs. 3a-3c. (a) **Tuning curve of basic system.** (b) **Curves of elastically connected portion.** ($T.C.$ = tuning curve ; $E.I.$ = effective-inertia curve). (c) **Resulting tuning diagram, showing the natural frequencies F_1 and F_2.**

Thus, $\mathcal{J}_2$ may be included either in the basic system or in the elastically-connected portion, or regarded as an independent mass. The study is simplified considerably by this last assumption.

To obtain the natural frequencies F_1 and F_2 of the complete system, the tuning curve of the basic system, and the effective inertia curve of the elastically-connected portion, are calculated and plotted as previously described, using eqs. (6), (6′) and (7), omitting the mass $\mathcal{J}_2$.

The resultant diagram is again obtained by superimposing the curves for the two-sub-systems. However, in order to take into account the effect of $\mathcal{J}_2$, the abscissae axis of the effective inertia curve must be displaced upwards by an amount $\mathcal{J}_2$.

This adjustment is necessary because the value of $\mathcal{J}_2$ is a constant which appears in the same manner in all the expressions for the curves of the basic system and the elastically-connected portion.

It can be justified analytically by considering eq. (3), which determines the tuning curve of a system, for a point of division situated near the end of the system, ahead of the last mass :—

$$\mathcal{J}_s = \mathcal{J}_n = -\left\{ \sum_{1}^{n-1} \mathcal{J}_i \, \theta_i \, \omega^2 \right\} \Big/ (\omega^2 \, \theta_n) \quad .. \quad (3)$$

With a concentrated mass at S, as shown in Fig. 3, the tuning inertia $\mathcal{J}_s$ will consist of two parts, viz. :—

$$\mathcal{J}_s = \mathcal{J}_2 + \mathcal{J}_y$$

where $\mathcal{J}_2$ = moment of inertia of the real mass concentrated at S, independent of the vibration frequency, and $\mathcal{J}_y$ = tuning inertia (as given by eq. (3)) of the fictitious mass concentrated at S, varying with frequency and depending on the elastic characteristics of the system. Therefore, instead of eq. (3), we now have $\mathcal{J}_s = \mathcal{J}_2 + \mathcal{J}_y$ or

$$\mathcal{J}_s = \mathcal{J}_2 - \left\{ \sum_{1}^{n-1} \mathcal{J}_i \, \theta_i \, \omega^2 \right\} \Big/ (\omega^2 \, \theta_n) \quad .. \quad (8)$$

Regarding this as the equation for the tuning curve of the elastically-connected portion, and taking account of eq. (7), we can write the equation for the effective inertia curve of this sub-system as follows :—

$$-\mathcal{J}_s = -\left[\mathcal{J}_2 - \left\{ \sum_{1}^{n-1} \mathcal{J}_i \, \theta_i \, \omega^2 \right\} \Big/ (\omega^2 \, \theta_n) \right] \quad (9)$$

This expression shows that it is justified to displace the frequency axis by an amount $\mathcal{J}_2$ in order to obtain the resultant tuning diagram of the original system (Fig. 3) and this procedure is applicable to systems with any number of masses.

Fig. 3a gives the tuning curve of the basic system of Fig. 3, omitting mass $\mathcal{J}_2$. Fig. 3b shows the tuning curve and the effective-inertia curve of the elastically-connected portion, omitting $\mathcal{J}_2$. Fig. 3c is the resultant tuning diagram for the entire system, taking account of $\mathcal{J}_2$.

SYSTEM OF n MASSES

In the general case, both the basic system and the elastically connected portion will consist of several masses and shaft elements. All the formulae previously used are still valid. The tuning curve and the effective inertia curves will be similar in appearance to those of Fig. 4. The basic system will again be represented by a family of curves having as many asymptotes as there are masses in the basic system. The curves of the elastically-connected portion will also be asymptotic, with as many asymptotes as there are masses in this part of the system.

The natural frequencies of the entire system are again obtained from the intersections of the two families of curves.

The significance of the asymptotes is as follows :— (1) The number of asymptotes is equal to the number of degrees of freedom of the system considered. (2) Each asymptote corresponds with one of the natural frequencies of the elastic system. Thus, the 1st asymptote serves to determine the frequency of the 1st mode, the 2nd asymptote gives the 2nd mode frequency, etc.

These properties of the asymptotes can be derived from eq. (2) regarded as a function of frequency.

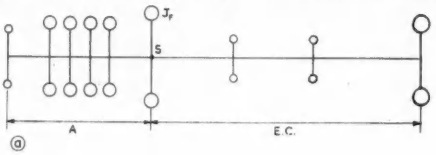
The tuning curves make it possible to study all the frequencies simultaneously. However, for a system with many masses this would result in an extremely complicated diagram. In practice, it is generally sufficient to plot a few branches only, both for the tuning curves of the basic system and the effective inertia curves of the elastically-connected portion. The reason for this is that in actual installations, only the lower natural frequencies (for instance, the 1-, 2- and 3-node frequencies) are easily excited and therefore likely to produce troublesome vibration.

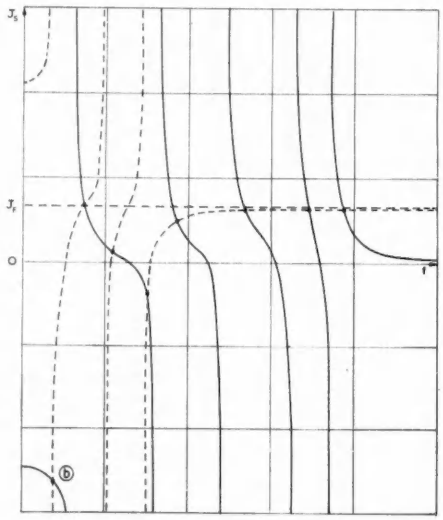
EXAMPLE OF A MARINE INSTALLATION

An interesting application of the principles described is given by the study of the various torsional vibration systems considered for the propulsion engines of the Argentine motor vessels of the " Rio de la Plata " class.

The installation comprises two double-acting ten-cylinder engines developing a total power of 9,200 hp. Each engine drives its propeller through line shafting approximately 60 metres long. Fig. 6a-1 shows the equivalent elastic system of the engine and line shafting arrangement, which consists of 22 masses and 21 shaft portions.

The point of division was chosen at the flywheel. The 14 masses and shaft elements on the engine side were regarded as the basic system, the 7 masses and corresponding shaft portions at the driven end forming the elastically connected portion.





Figs. 4a and b. **Nine-mass system.**

(a) Equivalent system (J_F = flywheel mass ; A = basic system ; $E.C.$ = elastically-connected portion).

(b) Resulting tuning diagram, with 8 points of intersection corresponding to the 8 natural frequencies of the system. (Full lines — tuning curves of basic system, dotted lines — effective-inertia curves of $E.C.$ portion).

The curves were calculated and plotted only for the range of frequencies extending up to 2000 vpm. This range includes the natural frequencies corresponding to the 1st, 2nd and 3rd modes of vibration, which are the

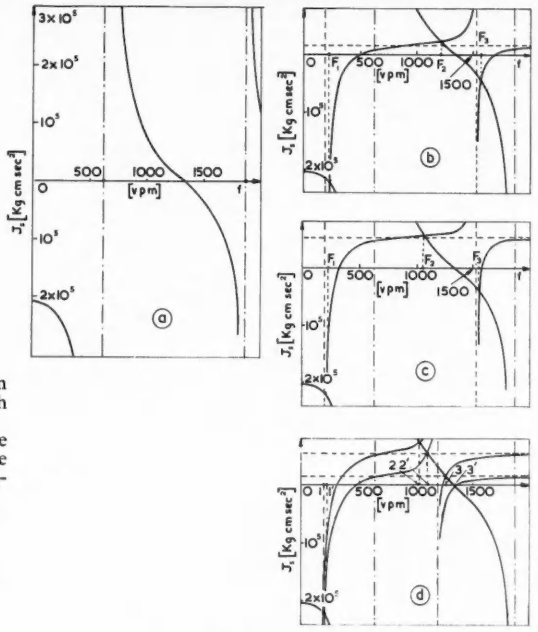


Fig. 5a. **Tuning curves of basic system.**

Fig. 5b. **Resultant tuning diagram of original system.**

Fig. 5c. **Resulting tuning diagram for first modification (heavier flywheel).**

Fig. 5d. **Resultant tuning diagram for second modification (two auxiliary masses) with curves for heavy and light flywheels.**

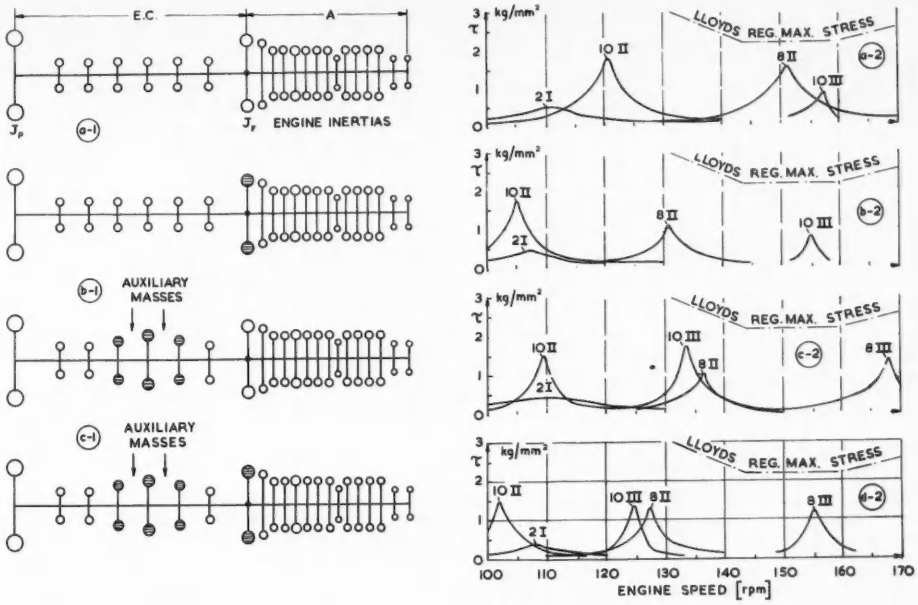
only modes of practical importance. The detailed calculations will not be given here, and we shall consider directly the various curves and the results derived from these.

Fig. 5a shows the tuning curves of the basic system, which will be regarded as invariable. Resultant tuning diagrams will be obtained by superimposing on these basic curves the effective-inertia curves corresponding to the various modifications considered for the flywheel, line shafting and propeller arrangement.

1. *Original installation* : The mass-elastic system is given in Fig. 6a-1. The tuning curves of Fig. 5a for the basic system, and the effective inertia curves of the elastically-connected portion, are shown superimposed in Fig. 5b. The latter curves are displaced upwards by an amount equal to the flywheel inertia.

The natural frequencies determined from the intersections of the two sets of curves are : $F_1 = 225$ vpm, $F_2 = 1210$ vpm and $F_3 = 1568$ vpm, for the 1st, 2nd and 3rd mode of vibration, respectively. These values were also obtained by means of the more conventional methods of calculation using Holzer tables. The measured frequencies, determined on board ship, were 225, 1190 and 1570 vpm.

The calculated critical speeds in the vicinity of the normal running range were the 8th order 2-node at 151 rpm and the 10th order 3-node at 157 rpm. The calculations predicted (see Fig. 6a-2) small vibration



Figs. 6a-6d. **Mass-elastic systems and crankshaft stress diagrams for the original and the modified systems considered.**

amplitudes. This was confirmed by measurements, the amplitudes being below the values allowed by the shipping registers. However, further possibilities of improving the existing conditions were considered in order to remove the critical speeds from the normal operating range which is between 150 and 160 rpm. The tuning curves method made it possible to analyse rapidly the results of possible modifications.

2. *First modification* : The original flywheel with a WD^2 of 5,010 kgm² was replaced by a larger flywheel with a WD^2 of 20,740 kgm², without altering the line shafting (Fig. 6b-1). The effective-inertia curve remained unchanged and had only to be displaced to the new value of the flywheel inertia (Fig. 5c).

The frequencies obtained from the intersections of the two families of curves are : $F_1 = 215$, $F_2 = 1055$ and $F_3 = 1553$ vpm. The measured values of 210, 1045 and 1560 vpm show close agreement.

The modification had the result of situating the critical speeds at approximately 132 rpm for the 8th order 2-node, and 156 rpm for the 10th order 3-node. Thus, whereas the first critical was displaced considerably, the second remained practically unchanged. However, the calculation showed that the stress amplitude due to the 3-node vibration was very low and practically insignificant (see Fig. 6b-2).

3. *Second modification* : Although the results obtained with the first modification can be regarded as satisfactory, it was decided to study a third mass-elastic system. Two small auxiliary masses were mounted on the line shafting, as indicated in Fig. 6c-1. These alter the shape of the effective-inertia curve. The resultant tuning diagram is shown in Fig. 5d. The new arrangement was also tried out with both sizes of flywheel previously considered, this being achieved by displacing the effective inertia curve by the corresponding amount in each case.

Using the light flywheel (Fig. 6c-1), the frequencies are : $F_1 = 219$, $F_2 = 1093$ and $F_3 = 1343$ vpm. The new arrangement removes both critical speeds from the vicinity of the operating range, the 8th 2-node being at 136 vpm, and the 10th 3-node at 134 vpm. These calculated values (see Fig. 6c-2) were found to be in good agreement with test results. Thus, although the critical speeds were well away from the normal operating range, they were also close enough to each other to result in a superposition of stresses, in spite of the phase differences.

With the heavy flywheel (Fig. 6d-1) the frequencies are : $F_1 = 213$, $F_2 = 1017$ and $F_3 = 1257$ vpm, placing the 8th 2-node at about 128 rpm, and the 10th 3-node at 126 rpm. Super-position of stresses is again obtained, but both orders give low stresses at speeds well below the operating range. There is an 8th order 3-node critical speed at 156 rpm, but calculations, subsequently confirmed by tests, showed that its amplitude is negligible (see Fig. 6d-2).

Thus, a study of the diagrams of Fig. 6 shows that the system will operate under more favourable conditions when the heavier flywheel is used without altering the line shafting ; or if the lighter flywheel is retained, by adding two auxiliary masses to the line shafting. In both cases, the critical speeds of any importance are removed from the operating range, and the corresponding stresses are well within the acceptable limits.

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Gaseous Nitriding

By A. MORGAN. (From *The Australasian Engineer*, June 7, 1951, pp. 82-89, 12 illustrations.)

This paper deals with the gaseous nitriding of the grades of steel commonly nitrided in Australia. The composition and conditions of supply of the various grades of Nitralloy are discussed, followed by an outline of the processing techniques required for preparing the material for nitriding. Also discussed are typical applications and limitations of the use of nitrided Nitralloy.

OF all the surface hardening processes, gaseous nitriding produces the hardest surface. The process was introduced by Dr. A. Fry of Germany in 1923. He studied the combining powers of various elements with nitrogen, when exposed to ammonia gas at the optimum temperature, and determined the stability of the resulting nitrides. From these investigations, he evolved a series of steels containing principally aluminium and chromium, which, when subjected to the action of ammonia gas at a temperature of around 500° C, were hardened at the surface without subsequent heat-treatment.

SOME THEORETICAL CONSIDERATIONS.

The source of nitrogen is the ammonia gas, which partially dissociates at the steel surface into atomic nitrogen and hydrogen. These are unstable and pass into the molecular form. The reactions are :

$$2NH_3 = 2N + 6H \quad (1)$$

$$2N = N_2 \quad (2)$$

and $$6H = 3H_2 \quad (3)$$

The atomic nitrogen is absorbed by the metal to form nitrides. Reaction (1) is catalysed to the right by iron, and even more by iron nitrides. The reaction rate thus increases as nitriding proceeds.

Molecular nitrogen is inactive ; hence, for successful nitriding, a supply of "active" atomic nitrogen must be ensured by continuously bringing fresh ammonia into contact with the steel.

Nitrogen forms an interstitial solid solution with iron and also forms the nitrides Fe_4N, or γ', and Fe_2N, or ϵ, as shown in the iron-nitrogen equilibrium diagram (Fig. 1). As a result of microscopic and X-ray studies, an explanation of the mechanism of nitriding has been proposed by Fisher and Shaw[1].

GRADES OF STEEL USED.

The grades of steel that have been specifically designed for nitriding are universally called Nitralloy. In Australia they are made in four main grades ; their composition is given in Table I.

It will be seen that they differ in carbon content only. This element determines the core properties after heat-treatment, the nitrided case hardness being approximately the same in each case.

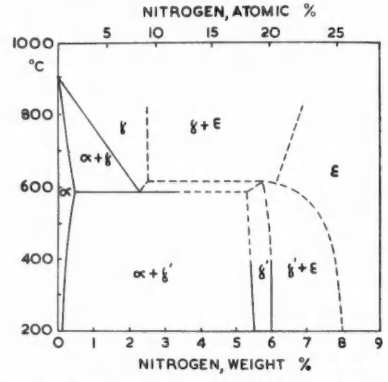

Fig. 1. **The iron-nitrogen equilibrium diagram.**

TABLE I.

	C %	Mn %	Cr %	Al %	Mo %
Nitralloy LK.1	0·50	0·55	1·60	1·10	0·20
Nitralloy LK.3	0·40	0·55	1·60	1·10	0·20
Nitralloy LK.5	0·30	0·55	1·60	1·10	0·20
Nitralloy LK.7	0·20	0·55	1·60	1·10	0·20

TABLE II.

	C %	Mn %	Ni %	Cr %	Mo %	V %	Al %	Se %
1	0·30	0·50	—	2·20	—	0·20	—	—
2	0·53	0·34	—	3·65	0·51	0·74	—	—
3	1·50	—	—	12·11	0·94	0·94	—	—
4	0·25	0·55	3·54	1·11	0·30	—	1·30	—
5	0·35	0·80	—	1·20	0·20	—	1·30	0·20

Table II sets out a few of the steels that have been developed for specific applications[2]. Steel 1 is used where extreme surface hardness is not required, only a tough case and core. Steels 2 and 3 were designed for very high core strength with a slight sacrifice in case hardness. Steel 4 was developed when it was found that nickel, in the presence of considerable quantities of aluminium, causes dispersion hardening of the core during nitriding. This means that such a steel can be tempered to a lower hardness than is required in order to promote machinability. The nitriding process increases the core hardness considerably, as is shown in Table III. Steel 5 is used in applications which

TABLE III.

	Before Nitriding	After Nitriding
Yield point (tsi)	51	80
U.T.S. (tsi)	59	85
% Elongation (2 in. gauge length)	22	15
% Area reduction	59	43
Brinell Hardness	277	445

demand free machining, especially where maximum impact properties are unnecessary. Most of these special steels are, however, not readily available in Australia.

PREPARING THE STEEL FOR NITRIDING.

Condition of Supply. Nitralloy should possess a fully heat-treated structure prior to nitriding. If nitriding is performed on annealed material, an iron-nitride network may form, causing the case to be brittle.

Bar stock of Nitralloy LK.3, LK.5 and LK.7 are normally supplied in the heat-treated condition. LK.1, which is used in applications requiring a high core strength (75 tsi and over), is normally supplied in the annealed condition. Heat treatment is performed after rough machining.

Forging. Nitralloy may be forged without difficulty in the temperature range 1150-900° C. Work should cease when the temperature reaches 900° C, and the material re-heated if necessary. The completed forgings should be cooled slowly by burying in warm dry lime, sand or ashes.

Welding. The welding of Nitralloy may be divided into two categories, as follows :

(a) Where welded to a steel of different composition and the surface hardness of the weld is unimportant,

standard methods of welding may be used. A low-hydrogen, lime-ferritic electrode is recommended for electric arc-welding.

(b) Where the weld is part of the working surface, and will be subsequently nitrided, it is essential that the weld material be of Nitralloy composition. Best results here are obtained by using the atomic hydrogen process, while electric arc-welding cannot be employed here because of heavy losses of chromium and aluminium.

When the weld metal is to be nitrided, the welded parts must be heat-treated after welding, and before machining and nitriding.

Heat Treatment. The heat treatment of Nitralloy is performed by quenching from 910-930° C and then tempering at 550-750° C, according to the core properties required. The material should be heated slowly and uniformly to the austenitizing temperature and held at the temperature for the times shown below :

Section	Holding time, hours
1 in. or less	½
1 in.–2 in.	1
2 in.–3 in.	1½
3 in.–4 in.	2

After quenching, the steel should be charged into the tempering furnace immediately and held at tempering temperature for one hour per inch of section.

Machining. The machining techniques required for Nitralloy are similar to those used on other heat-treated low alloy steels of the same tensile strength. However, Nitralloy steels have a much greater tendency to decarburise during heating for rolling, forging or heat-treatment than most other steels. As it is essential to remove all traces of decarburisation before nitriding, a machining allowance of twice that normally used is usually recommended for Nitralloy bars.

Stress relieving. In the rough machining of parts to be nitrided, internal stresses are set up, which must be removed prior to final machining and subsequent nitriding. This may be done by heating to a temperature approximately 50° C lower than the tempering temperature, holding for 3 to 4 hours and air cooling.

Prevention of nitriding and protection. It is frequently necessary to protect certain portions of an article, e.g., threads and keyways, against nitriding. Tin is commonly used as a protective agent, applied by electroplating or by a soldering iron or blowpipe. Excess tin should be removed, otherwise it may drop on to other parts in the nitriding container and produce soft spots. Although the nitriding temperature is above the melting point of tin, sufficient metal adheres by surface tension to prevent nitriding.

Sometimes it is more convenient to tin the part all over, and grind the portions which require hardening. Final machining of the protected areas is done after nitriding.

Other protecting agents are nickel, applied by electrolysis to a depth of 0·0005 in., or copper, to a depth of 0·0008 in. Copper plating is readily removed by chemical or electro-chemical methods after nitriding. In cases where complete protection is unnecessary, parts may be kept relatively soft during nitriding by the application of a paint composed of a mixture of aluminium powder and sodium silicate. Internal threads may be protected by packing tightly with asbestos wool, the surface of the plugged hole being sealed with aluminium paint.

The Nitriding Process.

Demand in Australia does not justify the installation of continuous nitriding units, and batch nitriding is used exclusively. A typical batch-type furnace and ancillary equipment are illustrated in Fig. 2.

The furnace. Automatically controlled electric resistance furnaces are normally employed. It is essential

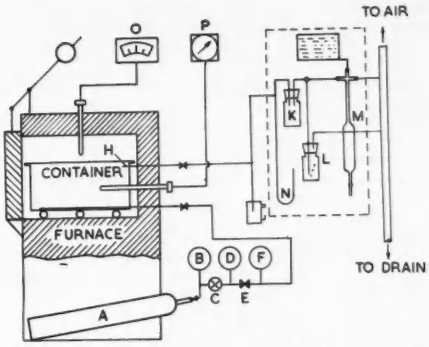

Fig. 2. **Nitriding equipment used in a batch-type unit.**
A—Ammonia cylinder, B—high pressure gauge, C—reducing valve, D—low pressure gauge, E—regulating valve, F—flow meter, G—inlet tube, H—outlet tube, J—seal pot, K—water trap, L—bubble jar, M—dissociation pipette, N—back pressure gauge, O—automatic pyrometer, P—indicating pyrometer.

to maintain the nitriding temperature within limits of ± 5° C.

The box or container. This should be made from material that will present an inert surface to the ammonia at the nitriding temperature. Enamelled low carbon steel has been used successfully, but is easily chipped. Welded high nickel-chromium alloy containers give excellent results. The most satisfactory alloys are Inconel (80 Ni, 12 Cr, 8 Fe) and heat-resisting steel of the 25/20 type (25 Ni, 20 Cr).

Sealing the container so that it is absolutely air-tight is very important. A very good seal is made of asbestos smeared with a paste of sodium silicate and Fuller's earth. A good test for leakage is to force ammonia into the sealed container, when escaping ammonia can be readily detected by smell or litmus paper.

Provision should be made for the insertion of a pyrometer in the container. The use of a fan is advantageous for uniform nitriding in larger units.

The ammonia train. A system of valves and gauges as shown in Fig. 2 controls the flow of ammonia, which enters the nitriding container through an inlet tube made from nickel or Inconel. The outlet tube is also made from either nickel or Inconel. The gas mixture from the outlet bubbles through a wash bottle tc indicate the rate of flow of the gas as well as the back pressure.

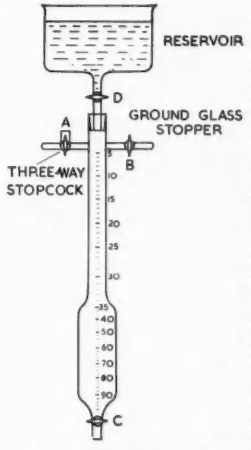

Fig. 3. **The dissociation pipette.**

The dissociation pipette. This instrument, shown in Fig. 3, measures the extent of the ammonia dissociation, and is based on the fact that ammonia is extremely soluble in water, while nitrogen and hydrogen are insoluble. The exhaust gas mixture is admitted into the graduated 100 cc. chamber through stop cock A. After all the air has been displaced, A is closed and D is opened. The water immediately absorbs the ammonia and reaches a level equal to the volume of ammonia present in the original mixture. As the pipette is graduated from the top, the water level indicates the percentage of hydrogen plus nitrogen in the mix-

ture. Actually the figure registered is not the true chemical dissociation, as the total gas volume increases during dissociation. However, it is a satisfactory basis for comparison.

Packing the container. Parts to be nitrided should be clean and free from grease or scale. As far as possible, articles which have parts protected should be placed at the bottom to prevent drops of the protective agent from contaminating other articles. Round shafts and spindles having tinned areas should be separated to prevent protected areas from touching each other, as otherwise tin may be drawn along the shaft or spindle by capillary attraction. The gas should circulate freely around all articles, which may be separated by nickel or Inconel wire grids. Articles in which a bore is to be hardened should be placed clear of the bottom, with the bore vertical. When nitrided in a horizontal position, the upper part of the bore may not harden properly, probably owing to a line of hydrogen bubbles being trapped in this position.

The nitriding cycle. After sealing the container and charging into the furnace, the ammonia supply is connected and the gas turned on. Correct flow is observed by means of the wash bottle. When all air is expelled from the container, the pyrometer is inserted and the charge heated. The time for nitriding is taken from the point when the required temperature has been reached.

Temperature is the main factor determining the hardness and depth of the nitrided case. Maximum hardness consistent with good case depth is obtained at 480° C. Deeper but much softer cases are obtained at 550° C. The possibility of nitriding at a relatively high temperature to obtain a deep case and then continuing at a lower temperature to increase surface hardness has been studied and various cycles established.[3] However, such cycles have not so far given consistent results.

When the nitriding temperature is reached, the degree of dissociation is determined by means of the pipette. A 25-35 per cent dissociation is to be aimed at throughout the cycle, and should be regularly checked.

The nitriding time varies from 10 to 90 hours depending upon the depth of case desired. The average nitriding cycle is 48-60 hours, which gives a case depth of about 0·012 in.-0·016 in., while a 90-hour period gives a depth of approximately 0·022 in. (Case depth is measured here from the point where a 25 per cent increase over core hardness is obtained).

If the temperature of the furnace falls for any reason, the ammonia should be kept running, but the time spent at the lower temperature must not be reckoned in the nitriding time.

At the end of the cycle, the temperature should be allowed to fall to 350° C before the ammonia is turned off. The inlet and outlet tubes are then connected with a piece of rubber tubing, and the container is allowed to cool to 180° C, when it can be discharged and the parts cooled in air.

If, for any reason, the ammonia supply fails, the inlet and outlet tubes should be connected so as to exclude the air from the chamber, and the furnace shut down. Nitriding can then be continued at a later time.

Final grinding and lapping. Most parts after nitriding have a comparatively soft surface layer of up to 0·002 in. thickness. For certain applications this is undesirable, and it is usual in these cases to grind and lap off this layer.

De-nitriding. This is sometimes necessary to carry out alterations or additional machining. It is performed by heating the nitrided component to a temperature of about 900° C and soaking at this temperature for several hours. It is not possible to re-nitride directly over a de-nitrided surface. The part must be heat-treated again and all traces of the original de-nitrided layers must be machined off. The main factor preventing the re-nitriding of a de-nitrided surface appears to be decarburisation.

Some Special Precautions and Recommendations.

The white layer. Fig. 4 illustrates the hardness *vs* depth of a typical nitrided case and indicates that the extreme surface is somewhat softer than the material at 0·002 in. below the surface, as mentioned above. This is known as the "white layer" because of its colour after etching. It is very brittle and is usually ground off. However, it is highly resistant to corrosion, and should not be removed where such a resistance is desired.

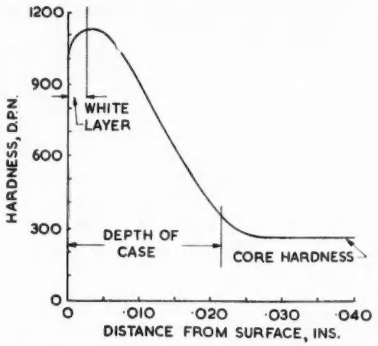

Fig. 4. Graph showing hardness *versus* depth of a Typical nitrided case.

It has been shown that the depth of the white layer is a function of the degree of ammonia dissociation, approaching zero at an 85 per cent dissociation[4]. Where it is impracticable to grind parts after nitriding, the white layer can be minimised by first nitriding at 30 per cent dissociation for about 5 hours and then increasing the dissociation to 85 per cent.

Decarburisation. The presence of decarburisation before nitriding results in the formation of an extremely brittle case which readily spalls. On cyclindrical articles sometimes a brittle strip, caused by decarburisation, is produced along one side. This can be attributed to an error in centring, which causes insufficient removal of metal at this position.

Growth. The absorption of nitrogen during nitriding leads to an increase in volume of the nitrided case. This increase causes tensile stresses in the core after cooling, balanced by compressive stresses in the case. The magnitude of the growth increases with the temperature and time of nitriding, and also with the increase in the amount of free ferrite in the original structure.

Because of growth, sharp corners should be eliminated in the design of nitrided parts, as such corners suffer augmented growth and become very brittle.

As an indication of the amount of growth to be expected, a sample of 0·7 in. dia. Nitralloy LK.3, nitrided at 510° C for 48 hours, increased 0·001 in. in diameter. Under similar conditions, growth is constant.

Colour of finished article. Parts properly nitrided should be silvery grey in colour. Discoloration will result if the nitrided parts are exposed to air before they are cooled to 180° C, or if there is air leakage in the nitriding container, the latter usually causing variations in hardness.

Advantages, Applications and Limitations of the Nitriding Process.

Unparalleled surface hardness. The surface hardness of a nitrided case produced on Nitralloy, when processed correctly, is well in excess of 1000 D.P.N., values as high as 1400 D.P.N. having been reported. The maximum hardness of a carburised case is in the vicinity of 850 D.P.N. This fact makes nitrided parts eminently

(*Concluded on page* 313)

How to Overcome Materials Shortages in Product Design and Manufacture

By H. R. CLAUSER. (From *Materials & Methods*, Vol. 34, No. 1, July, 1951, pp. 89-112 and 112A-112H, 33 illustrations.)

WHAT are the ways to overcome material shortages ? Practically every manufacturing industry is faced with this problem. This article gives a survey of the various possible solutions which are being developed for specific requirements.

The following useful suggestions can first be made :—

1. Stretch your available supply of scarce materials, by (a) simplifying ; (b) reducing waste ; (c) reclaiming scrap ; (d) salvaging rejects ; (e) using less scarce material per item ; (f) using a combination of the scarce and a more plentiful form of the material.
2. Use a down-graded composition of the scarce material.
3. Change to another, more plentiful material, by (a) using an alternative material with or without design changes ; (b) using an alternative material plus processing, such as heat treatment, to obtain the desired properties ; (c) using an alternative material plus a surface finish or treatment.

In more cases than is often realised, the replacement material proves to be superior to the scarce material it replaces, and, consequently, continues to be used even when the former material again becomes available. The solution to the problem of material shortages lies in practising good materials engineering which, in essence, is the selection of the best *available* material to produce the highest quality product at the lowest possible cost. With materials supply and demand constantly fluctuating, what may be an alternative material this month may become a critically scarce material the next. Often, the very fact that a material is available as an alternative causes it to come into great demand and precipitate a shortage. Thus, in 1942, wood was considered a good alternative for steel in many products, but in 1943, when wood became scarce and steel more plentiful, steel served as an alternative for wood.

SIMPLIFICATION.

A good simplification programme is one of the first steps towards making it possible for available or allotted supplies of materials to stretch further. It means surveying and reducing any excess variety in materials, grades, sizes and models of products. The survey will indicate the items most widely used and most economical in scarce materials, which can be retained, while others can be discontinued, at least for the time being.

Many companies and entire industries achieved great savings in materials during World War II. For example, the number of different iron, brass and bronze valves was reduced from 4079 to 2504, resulting in an extensive saving of carbon and alloy steels and copper. The sizes and weights of cast-iron radiators were reduced, thus saving 23,000 lb of cast iron per annum. Savings estimated at 10,000 tons of sheet steel and 2925 tons of cast steel and iron were obtained by using standard steel sheets of 60-inch width without shearing or cutting waste in the manufacture of range boilers (types reduced from 156 to 12) and expansion tanks (sizes reduced from 13 to 5).

In the present emergency, elimination of unnecessary variety is essential. In carrying out a strict simplification programme, the following general principles should be kept in mind :—(1) A sufficient and satisfactory variety of grades and sizes should be retained. (2) Selection should provide sufficient ranges of quality and quantity in economical steps, with grades and sizes in line with national practices to provide maximum availability. (3) Where more than one plant is involved, co-ordination and adequate interchange of information should be provided for exchanges of stocks. (4) The programme should be flexible enough to allow for the addition of promising new items and the elimination of superseded items whenever indicated.

REDUCTION AND RECLAMATION OF SCRAP

Where the use of certain scarce materials is permitted, but supply is limited, a thorough-going salvage programme is particularly important. For example, one refrigerator plant is returning almost 3500 tons of pressed metal rejects, shearings, etc., per annum to the productive cycle. One automobile company estimates that by re-working its sheet scrap, it can make about one extra car for every 50 produced, and it is also re-using about 22 per cent of its sheet clippings for such things as washers, caps, flanges, brackets, and cover plates.

It is sometimes desirable to change the design in order to make the best use of scrap, such as shearings, skeletons, trimmings, and bar ends. Modification of tool design may also permit the use of a shearing or offcut piece without the necessity of first trimming or blanking the piece. Slugs or blanks of uniform size from press operations can often be magazine-fed in the press production of smaller parts.

Instead of being discarded, obsolete metal stock, such as tubing, sheet and rod, can frequently be adapted for productive use elsewhere or used for non-productive purposes by the maintenance department. Scrap can also be reduced by salvaging rejects and developing good repair procedures which will not increase costs excessively. For example, scrap was high on a certain bearing plate in a refrigerator owing to a flapper-valve seat not cleaning up because of shrink holes in the castings and some oversize bores on the valve cavity. By making the bore 0·020 in. larger and dropping the seat 0·050 in., it was found possible to use a larger and deeper salvage valve retainer, with the result that 95 per cent of the bearing plates were salvaged.

REDESIGN TO ANOTHER FORM

Another means of using less material or reducing waste is by converting from one metal form to another. Castings can often replace fabricated assemblies, and stampings take the place of forgings. In view of the scarcity of machine tools, machined parts should be replaced wherever possible.

For instance, a 5-inch anti-aircraft shell adaptor, formerly machined from steel bar stock weighing $3\frac{3}{4}$ lb, is now made as a malleable iron casting, cast close to size and weighing about $2\frac{1}{4}$ lb. A roller cage of a torque converter, formerly consisting of two rings and 20 hardened and ground pins with soft-shouldered, riveted ends, is now made as a one-piece stamping. In another case, a bomb-fin crate locknut assembly was replaced by a stamped clip. Another interesting case is that of a water-tight connector used in electrical systems of aircraft or land vehicles. One member is a thin aluminium shell with a square flange. The pilot lot was turned from bar stock and the inside diameter and key were broached. In view of the vibration to which such parts are subjected, the only other satisfactory method was an extruded hot die pressing. By this method, the weight of rod required is only 0·136 lb per piece, compared with 0·454 lb for the machining method, the finished piece weighing about 0·057 lb.

Powder metallurgy offers many possibilities for such parts as pistons, gears, and cams. The finished parts can be produced without any subsequent machining in many applications. Precision can also be successfully used. For instance, a microwave mixer and guide body casting is now being made of investment cast aluminium

as a single piece, instead of consisting as previously of more than 20 components assembled by silver brazing.

There has been a growing use of extrusions in aluminium, magnesium and copper-base alloys, and in recent years the extrusion process has been extended to steel, permitting the production of complicated shapes and saving large quantities of metals and machining time.

Thin sheet-metal sections can be " rigidised " for increased strength and flexural rigidity, and such sheets have been used, for instance, for railway coach wainscoting. Rigidising can also be applied to salvaging dented, scratched, bent or otherwise damaged cut-outs and blanks.

Use of Composite Metals

Composite or clad materials can be used wherever stainless steels, nickel and nickel-base alloys, copper and aluminium are used in plate, sheet or strip form. The most common types of composite metals are the clad steels, generally consisting of a plain low-carbon steel used as backing, while the cladding may consist of stainless steel, nickel, monel, Inconel, copper, cupro-nickel or silver.

Generally, single-clad steels cannot be used for temperatures above 1000° F or below —50° F. Clad steels are usually fabricated by welding. Precautions for corrosion-resistant applications must be taken to avoid or minimise dilution of the weld metal by pick-up of the backing steel, since otherwise the corrosion resistance at the joints may be sufficiently lowered to cause failures. Extensive use of clad steels is made in chemical and food processing, for storage tanks, reactors, autoclaves, tank cars, degreasers, evaporators, cookers, bottling machines; in petroleum refining, for crude towers, heat exchangers and catalytic reactors ; in the heat-treatment field, for annealing furnaces and salt baths ; and in the power generating field, for coal chutes and condensers.

Other combinations of clad metals include copper-clad aluminium, silver-clad aluminium, aluminium-clad iron, nickel-clad iron, and stainless-clad copper. Besides serving to extend supplies of scarce materials, composite metals frequently combine properties which are not available in single metals, such as superior strength and reduced cost.

Copper-clad steel has been successfully used for radiator tanks in water-cooled internal combustion engines, the clad metal being 0·025-0·031 inch thick (tubes excluded), and since the copper or copper-alloy cladding is generally thicker than that in the tubes, its service life is quite satisfactory. This saves about 70-80 per cent of copper.

Composite metals can be extensively applied for hardware fixtures (for instance, drive-way lamp fixtures made of copper-clad steel). Aluminium-clad low-carbon steel of suitable thickness is now being used for anodes of radio valves. The aluminium-clad steel does not have to be carbonised, the anodes being heated to a temperature somewhat above the melting point of aluminium. Thus, aluminium ferrites form on the surface, giving the parts radiation characteristics fully comparable to those of carbonised nickel.

In close-spaced rectifiers, nickel-clad steels, with about 10 per cent steel on each side of a low-carbon steel, replace solid nickel and thus permit nickel savings of 80 per cent. The nickel-clad steel is carbonised in the same manner as solid nickel. Further savings of nickel and chromium are obtained by adopting stainless-clad vessels in place of solid alloys for vessels previously made of stainless steel or solid nickel material.

Model trains are now being made from alternative metals. Gears with longer life and no machining requirements are made from various metal powder compositions. Non-magnetic, spot-welded eyelets, previously of nickel-silver, are now replaced by press-fitted phenolic mouldings. Bumper assemblies, previously made as zinc die-cast bodies, are now plastic injection mouldings. The contact rollers on the lorries, formerly a screw machine part of stainless steel, with a roller bracket made of phosphor bronze strip stock, are now manufactured from a metal powder roller composition, with 8 per cent nickel and the balance of copper, and a cold-rolled steel roller bracket, resulting in a substantial saving in cost and approximately doubling the life of the unit. Iron-powder magnet poles are used, which also act as bearings for the wheel axle, thus eliminating the phosphor bronze bearings previously used and saving 40 grammes of Alnico material per unit.

Hard Facing

Hard facing can be applied in the production process to provide a hard overlay on less critical carbon steel, in order to improve wear, heat and corrosion resistance. It can also be used to rebuild worn surfaces of earth-working, processing and handling equipment, such as, for instance, tractor rollers.

Use of Less Scarce Material per Item

Savings in scarce material can be obtained by re-designing the item to another form, and using composite materials. It is also indicated to study ways of confining scarce materials to the portion of the part or product where they are indispensable, more plentiful materials being adopted for less critical spots. Furthermore, many products are over-designed in normal times, and in many cases section thicknesses can be reduced without impairing service life.

" Miniaturisation," or the reduction in size of components, is another way of saving strategic materials, as well as space and weight. This is being achieved in the electronics field, for instance, by using iron-powder cores or ferrite cores for high-frequency transformers, replacing rectifier valves by crystal rectifiers, and designing sub-miniature radio valves.

CONSERVATION AND REPLACEMENT OF SCARCE MATERIALS

In this section, various methods evolved will be considered, and the scarce metals are dealt with in alphabetical order.

Alloy Steels : The SAE type constructional alloy steels are bing replaced to an increasing extent by the National Emergency (NE) steels of the nickel-chromium-molybdenum " XX " steel series, developed during World War II. These NE steels are devised on the principle that, if two elements are equally effective, a greater hardenability will be obtained by using one-half as much of each of them. However, in heat treatment, the temperature must be held within about 100° F as compared with 200° F for the high-nickel alloy steels. The following table* gives a list of NE type alternatives for standard steels :—

Standard steel series	NE type alternatives	Standard Steel series	NE type alternatives
1300	8600	4600	8600(3)
2300–2330	8700	4800	no general alternative
2335 & higher	8600 + 5% carbon (1)	5000	special low alloy
2500	9300(2)	5100	8600
3100-3130	8600-8700	52100	no general alternative
3135 & higher	8600 + 5% carbon	6100	8600
3300	9300	8600	no change
4000	9700	8700	no change
4100-4130	8600	9200	8600
4132 & higher	8700 + 5% carbon	9300	no change
4300	no general alternative	9400	8600
		9700	no change
		9800	no change

(1) For low-temperature applications, consider use of a heat-treated product. (2) Except for low temperatures and corrosive conditions. (3) For bearings, RBEC 4700 may be necessary.

*For details of composition, see Kent or Machinery Handbook.

Boron steels, designed to conserve manganese, nickel, chromium and molybdenum, are being introduced commercially and should rapidly find wide application. Their chemical compositions and engineering possibilities are reviewed in another article in this issue.

Three further new groups of steel have been introduced :—The TS86XX is designed to replace, for light sections, the standard 86XX steels. Compared with the latter, the TS86XX has a somewhat lower molybdenum content (0·08-0·15 per cent) and a somewhat higher chromium content (0·55-0·75 per cent). The TS81XX is similar to the previous series, but has a higher nickel content (0·2-0·4 per cent) and less chromium (0·3-0·5 per cent). The third group, 4137-INT, is intended to replace 4100 steels and to save molybdenum.

In a large number of cases, a satisfactory alternative for alloy steels is obtainable by using carbon steel with a proper selective area or surface heat treatment. The use of sections having increasing thickness is also suggested as a possibility.

ALUMINIUM : The metals that were originally replaced by aluminium are the obvious alternatives for this material, but copper alloys and alloy steels are themselves scarce. Magnesium, which is still unrestricted, has many characteristics and properties similar to those of aluminium, and can replace aluminium in many indoor applications.

Other alternatives are steel, cast iron and non-metals such as plastics, wood, glass and ceramics. In cooking utensils, for instance, formed sheet steel with an enamel coating can be substituted. Oiled paper, glassine, lead foil or cellophane can replace aluminium in many of its uses. For bottle caps, aluminium can be replaced by painted steel or paper. Appreciable amounts of aluminium can be conserved by reducing the amount of aluminium used as an alloying agent, for instance, in zinc-base die castings.

Savings in aluminium can frequently be obtained by reducing scrap from blanking and forming operations and carefully salvaging aluminium scrap, especially in the foundry. Minor changes in design or layout, and the use of thinner sections of aluminium alloy of higher strength, when these are available, can be introduced with advantage, incorporating reinforced ribs where necessary.

CHROMIUM : Since there is no great shortage of chromium at present in the U.S.A., it is being relied on heavily as an alloying element in place of other, scarcer, metals, such as nickel, and is extensively used in corrosion and heat-resistant alloy steels.

COBALT : At present, one of the scarcest materials, cobalt, is in great demand both for permanent magnets and high-temperature alloys. The use of electromagnets instead of permanent magnets can help to conserve cobalt supplies. Superfine iron-powder materials with properties comparable to those of Alnico magnets have recently been developed abroad. In the extremely high performance magnetic alloys, there is so far no known substitute for cobalt. However, chromium-cobalt magnet steels can be replaced by chromium-molybdenum dispersion-hardened alloys. Where no forging or machining is required, nickel-aluminium alloys containing no cobalt or up to about 5 per cent cobalt can be substituted for chromium-16 per cent cobalt alloys. Tungsten-cobalt steel types may be replaced by various iron-nickel-aluminium alloys of the Mishima type.

As regards heat-resisting alloys, there are no substitutes for the cobalt-base alloys for temperatures above 1600° F. Although combinations of ceramics and metals are being worked on, the only solution at present seems to be to keep operating temperatures below 1600° F using stainless steels and high nickel-chromium alloys.

COLUMBIUM : In stainless steels, this scarce element is used as a stabiliser (see : Corrosion and heat resistant steels). In some cases, regular columbium ferro-alloy is being replaced by a tantalum-columbium ferro-alloy as an alloying ingredient. For welding-electrode coatings, columbium is also being replaced by tanalum.

COPPER : The shortages in copper and copper alloys are not easy to overcome. The suggested solutions are : (1) switch from copper or high-copper alloys to low brasses where possible ; (2) redesign to use less copper per item or switch to another material, without undue sacrifice in quality or service life of the product.

For electrical applications, aluminium is the only practical alternative, but is also scarce. Moreover, because aluminium has only about 61 per cent of the conductivity of copper, an aluminium part must be about 1·5 times larger in dimension than a copper part, and this raises problems for rotating machines, transformers, etc. In the electrical and electronic fields, printed circuits are being used in place of copper wiring. For lead-in wires on lamps, the gauge size or length of wire can be reduced.

For non-magnetic or corrosion-resistant applications, coated steels and irons as well as non-metallics will have to be used. Copper-plated steel or copper clad steel can be used instead of solid copper. Solid bronze bearings are being replaced by steel-backed bearings, and solid brass designs by steel and iron hardware or, in some cases, by combinations of steel and brass. As in World War II, a shift from brass to steel cartridge cases is underway, and the U.S. Army Ordnance is seriously considering the adoption of iron-powder rotating bands in place of gilding metal ones.

CORROSION AND HEAT-RESISTANT STEELS AND IRONS : Many stainless steels contain columbium and nickel, and the problem of selecting alternatives is, thus, largely one of finding suitable alloys not containing these two elements.

In the welding grades of stainless steel, columbium is used as a stabiliser to prevent the precipitation of brittle carbides in the welded joint. Titanium is considered by some experts to be a better stabiliser than columbium, the proportion added to carbon being 10:1 for columbium, whereas it is only 5:1 for titanium. The stainless steel type 347 can thus usually be replaced by types 430 or 321 which are stabilised with titanium. An alternative is to choose a grade in which the carbon is adjusted to a maximum of 0·03 per cent, at which maximum improvement in preventing carbide precipitation is obtained, so that stabilisation is not necessary.

For high creep strength at elevated temperatures and special corrosion resistance, the molybdenum-bearing grades of stainless steel of type 318 can be replaced by type 316, of similar composition but without columbium, the carbide precipitation being controlled by using low carbon. These low carbon stainless steels should not be continuously exposed to temperatures above 800° F, since this would result in gradual carbide precipitation.

Heat treatment after welding, to dissolve the precipitated carbides, is another method used to eliminate carbide precipitation in unstabilised grades. The steel is heated to about 1950-2050° F and quickly cooled to below red heat, but this treatment is not always economical or practical.

Nickel-bearing types of stainless steel, and particularly the 188 alloys, can be replaced by alternatives having sufficient alloy content to give satisfactory corrosion resistance with appreciably reduced workability. Thus, the alternate steel type 410, with 12 per cent chromium, will be less suitable than the type 430, with 17 per cent chromium, which has improved workability, especially when produced with extra low carbon. The type 430 is successful as an alternative if the fabricating requirements and the corrosive conditions are not too severe and if the alloy is frequently cleaned in service. Although it may not be fully satisfactory for hospital, chemical, brewery and dairy applications, its oxidation

resistance is good so that it will be suitable for most uses in furnaces, kitchenware, counter tops, ice cream cabinets, etc., which are cleaned frequently. The 430 alloy has a rather low ductility, and tendency to embrittlement limits its weldability, but modified practice should make it a satisfactory substitute.

As regards stainless steel pipes, the Schedule 40 pipe is being replaced by the new light-walled Schedule 5, which provides 2-3 times the pipe footage per pound of stainless steel. This pipe can withstand working pressures up to 150 psi.

Many castings formerly made of a 65 nickel 15 per cent chromium iron alloy can be replaced by down-graded compositions, such as the 35 nickel 15 per cent chromium composition, although this may result in somewhat shorter service life.

When chromium type steels of the 400 series are unavailable or unsatisfactory, further possibilities to be considered are the use of (1) low carbon steel with corrosion-resistant coatings (glass, ceramic, conversion concretes, or refractories) ; (2) clad steels ; (3) plain carbon steel. The latter can only be applied where there is no pitting corrosion and where increased section thickness can be used to compensate for corrosion.

For elevated temperatures, in many cases carbon steels can be used up to about 825° F, and ferritic grades for temperatures from 800 to 1050° F. Above this figure, titanium-stabilised 188 grade alternatives are being introduced. In many industrial high-temperature applications, a good alternative is obtained with silicon carbide refractory material, which has the characteristic of increasing in strength and rigidity up to 2500° F. Successful use of this material has been made in radiant tubes and roller hearths for heat-treating furnaces.

MANGANESE : This metal is being extensively used in place of scarcer metals for alloying. Its replacement by zirconium is being considered in the event of the supply position becoming critical.

MOLYBDENUM : In a number of steels, this scarce metal can be replaced by vanadium. New alternate steels containing considerably less molybdenum have recently been introduced.

NICKEL : The three major fields of use of nickel are : (1) as an alloying element in iron and steels (over 50 per cent of the total nickel production is used for this purpose) ; (2) for plating (10-15 per cent of total nickel production) ; and (3) in its commercially pure form or in high-nickel alloys, such as monel, Inconel, etc. (30 per cent of total nickel production).

Down-graded nickel alloys are not being produced commercially, and are not a practical solution, since copper is as scarce as nickel. However, possible alternatives are : (a) nickel-alloy clad steels (see : Use composite metals, p. 294) ; (b) stainless steels with smaller nickel content, such as the 188 types below 1600° F, and types 309, 310 or 330 for temperatures above 1600° F ; (c) porcelain-enamelled steel, glass, and corrosion-resistant coatings.

NICKEL IN PLATING : Various replacements for nickel in electro-deposited coatings have been tried and found to be quite satisfactory ; in some cases, the substitutes are at least equal to nickel. The various methods so far applied are reviewed in the following lines.

Less nickel : Chromium-plated steel parts for outdoor use are now commonly being made of 0·00065 in. copper, 0·0006 in. nickel, and 0·00001 in. chromium. Considering that copper and nickel provide about equal protection to steel, some engineers specify a combined thickness of copper and nickel. A further method is to reduce the nickel to 0·0002 in., keep the normal copper and chromium thicknesses, and coat with a clear nitrocellulose-acrylic lacquer or urea-formaldehyde baking enamels.* Coating thicknesses increased to 0·001 in. are used to compensate for reduced nickel thickness in cases where clear synthetics were normally used with nickel plating, as in refrigerator shelves, etc.

Copper, chromium and synthetic : Nickel can be omitted entirely for some applications, the steel being plated with copper and chromium and coated with a clear synthetic. A high-quality smooth finish is obtained with periodic reverse-current plating, and this has been successfully applied to electric irons, etc.

Zinc and bright dip, or zinc and chromium : To replace either nickel or cadmium plating, zinc-plated steel can be dipped in a chemical solution to obtain a transparent colourless coating. The process is suitable for many indoor applications, or where exposure is not severe. A clear enamel or lacquer applied over the dip coating will increase its durability. An alternative method, under patent application, permits electro-deposition of decorative chromium plate : A 0·0003 in. thickness of zinc is deposited on the base metal, followed by a bright dip and by a chromium coating.

Other Methods : Nickel can be conserved by plating only functional parts, keeping dragout of solution to a minimum, and obtaining more uniform deposit thickness by racking work. Synthetic organic enamel type finishes, resembling a chromium finish, are being used on lamps, bathroom fixtures, metal furniture and hardware.

RUBBER : Synthetic types of rubber are being used wherever possible. There are now about 640 different types of the GR-S type synthetics, which are superior to natural rubber in regard to oil resistance and high-temperature resistance. Owing to their high hysteresis loss, synthetic rubbers reach higher operating temperatures than natural rubber, and this may cause premature failure. Modified tyre designs, with cotton instead of rayon in the carcass, are now being used to overcome this difficulty. Butyl-type synthetic rubber has proved itself satisfactory and is now being used almost entirely for inner tubes.

For many mechanical goods and such products as mats, flooring, etc., reclaimed rubber, both synthetic and natural, is suitable.

A new type of synthetic, known as "cold rubber," has recently been developed. Polymerised at about 40° F instead of 120° F for the GR-S types, it has a reported 30 per cent better wear resistance than natural rubber, as well as about 35 per cent greater tensile strength. However, its hysteresis properties are still inferior to those of natural rubber. Cold rubber can be used for wire insulation, footwear and belting, and foam rubber. A cold rubber permitting saving in styrene, and using polybutadiene, is now being developed.

TIN : The methods of conserving tin supplies, learned during the last war, are still valid :—Lead-silver solders are substituted for tin solder, except for soldering black iron or bonderised stock ; lead burning replaces wiping solder ; silicon bronzes, etc., are satisfactory in place of tin bronzes ; and lead-base babbitts replace tin-base babbitts. As a substitute for high tin-base babbitts, a lead-base babbitt containing colloidal graphite has been produced. The graphite is homogeneously distributed throughout the metal and is said to provide good bearing properties.

For cans, lacquered bonderised steel, or tern plate (20 tin, 80 per cent lead), are being used. Other non-food containers are made from black iron sheet stock with a protective enamel coating and a seam sealer of plastic cement. A new low-tin solder having 2 per cent instead of the usual 40 per cent tin content has been developed for sanitary cans. Tin coatings having a thickness one-fifth of that formerly used can be obtained by electroplating instead of hot dipping. Savings can also be achieved by using a thinner coating outside the can than on the inside surface.

In photoflash lamps, tin is being saved by reducing the

*See *The Engineers' Digest*, May, 1951, p. 145.

tin content in the solder and reducing the diameter of the solder wire. In many cases, lead with an organic lining in place of tin is suitable for collapsible tubes.

TUNGSTEN : There are really no alternatives for tungsten in regard to high-speed tool steels, permanent magnet materials and high-temperature materials. Many precautions against wastage are being taken in the production of tungsten wire for lamp filaments, and scrap tungsten is even being re-processed in some cases, despite the cost.

VANADIUM : This metal is an important ingredient in high-temperature alloys and in some tool steels. It is being used in place of molybdenum in a number of alloy steels, since it is relatively more plentiful.

ZINC AND CADMIUM : The present scarcity of zinc is probably due to its wide use as an alternative material. As in World War II, steel cartridge cases are again being used in place of brass, and this will save large quantities of copper and zinc.

Zinc die castings can be replaced either by aluminium, steel, cast-iron and malleable iron castings, or by steel stampings in certain cases. The use of smaller-size castings, and resort to moulded plastics as a possible alternative, should help to stretch the available supply.

Zinc plating is replacing cadmium plating and nickel plating, and is found to be less expensive than either of these, particularly in business machines and in steel or copper aircraft parts. It is not used for the following components : parts subjected to frequent sea water immersion or spray, for which tolerance requirements will not permit 0·001 in. plating ; moving parts where tolerances with zinc plating cannot be maintained in service ; parts which in service reach 700° F ; electrical components soldered with rosin-type non-corrosive fluxes ; and certain parts of electronic equipment. Long-time exposure tests to salt spray and outside air proved that the bright-dip zinc-plated parts had a better appearance than cadmium.

For still-plating procedures, no change is necessary, but new tanks were required for barrel plating. The temperature control for zinc plating being more critical, tanks with heating and cooling coils were used. The nitric acid dip used to improve plate appearance in cadmium plating was replaced by a chromic acid bright dip, which inhibits corrosion.

For zinc used as a replacement for galvanised steel, organic finishes or chemical surface treatments such as phosphate coatings should be considered. Phosphate coatings plus a wrinkle finish can give a very satisfactory result.

HOW ALTERNATIVE MATERIALS CAN HELP

CARBON AND GRAPHITE : Besides being used for packing rings, piston rings, bearings and valves, carbon and graphite are being used for carbon clutch rings to replace ball thrust bearings in motor cars. Rayon finishing mill bearings, sealing rings for fluorescent tubes, pouring spouts, dies and moulds for powder metallurgy, are some of the newer uses of these materials.

CERAMICS : Alumina-type ceramics with a hardness of 9 on Moh's scale and a flexural strength of 40,000 psi are suitable for use as extrusion nozzles for extruding ceramics, soft wires, and pencil leads, and are also used as guides for threads and recorder wires. In high-temperature applications, such as burner tips and nozzles, welding tips, brazing jigs and fixtures, as well as in jet engines, rockets and gas turbines, ceramics are finding increased application. Ceramic surface plates can replace cast iron. Ceramics can be produced with the dimensional accuracy of precision metal parts and successfully replace steel where wear resistance is involved.

FIBROUS MATERIALS : These are useful alternatives for plastics and metals. Vulcanised fibre is used for certain types of gears and as an overlay in sandwich materials. A material known as " Duroid " is being employed for the insulation of electrical fittings.

FINISHES AND SURFACE TREATMENTS : Besides the finishes described in foregoing sections, mention should be made of metallising as another means of replacing scarce metals. For instance, a clear plastic moulding metallised on the underside obtains the appearance of chromium plate and is used for name-plates, in place of a painted aluminium stamping. A bright aluminium coating can be used as a substitute for nickel and chromium plating, and a wide variety of possibilities is offered by surface conversion and metal colouring treatments.

GLASS : Obvious uses of glass are to replace metals in cabinet shelves, casings for heating furnaces, table and counter tops, record discs and linings for plating tanks. For drying racks in tanneries, etc., plate glass can replace aluminium and stainless steel. Kick plates on doors can be made from heat-treated glass, which is five times stronger than conventional plate glass. Stair treads can be made from wire glass, and glass is being adopted for instrument panel backboards, tubing previously made of brass or copper, etc. Glass of very high resistivity has been used in the form of thin strips as dielectric in small condensers, in place of mica.

LEAD : Extensive use of lead is being made for replacing steels, copper tubing and piping. It is also replacing aluminium foil, for decorative purposes and for packaging as a moisture barrier layer. Lead-headed steel nails have been developed for fastening aluminium. Collapsible tubes, coated inside with an organic finish, are also being used for packaging.

MAGNESIUM : A new electrolytically applied coating, known as " HAE," has been developed as a finish for magnesium. It has excellent corrosion resistance, high hardness, good dielectric strength and a high melting point.

PLASTICS : The supply of vinyl and cellulosic plastics is fairly plentiful, but polyesters, styrenes, phenolics and acrylics are scarce. Plastics are saving considerable amounts of steel, copper and aluminium, as well as rubber, by being adopted for many military items, such as mine detectors, body armour, mess hardware, medical tubing, lenses, reflectors, gun stocks and grips, and cable insulation. In refrigerator parts, vacuum cleaners, accounting machines, electronic engraver housings, etc., steel, aluminium and other materials have been successfully replaced by plastics and reinforced plastics. The latter consist of resins and reinforcing materials such as cotton, glass fibre, hemp, paper, rayon, and sisal.

PORCELAIN ENAMELS : Where corrosion resistance and heat resistance are involved, porcelain or vitreous enamels on mild steel or iron are often suitable. Chemical attack from sulphuric and nitric acids, or from the chemical encountered in the food, pulp, paper and dye industries, can be resisted by porcelain enamels, which are reliable alternatives for stainless steels. However, chemicals containing free caustics will attack porcelain enamels, although for hot-water heaters and laundry tubs some special alkali-resistant enamels have been developed.

Heat-resistant ceramic coatings are being successfully used on parts operating up to 1900° F. For mufflers, exhaust manifolds, aluminium melting pots, and steam boiler pre-heater parts in contact with hot gases, porcelain-enamelled steel is adopted. Porcelain enamel has been used as a coating for nitriding equipment made of ordinary iron. Enamel-coated steel or iron can also replace copper alloys in pickling tank fixtures, etc. Porcelain-enamels are also being adopted as alternatives

(*Concluded on page* 310)

RUSSIA

The Influence of Surface Roughness upon the Impact Strength of Steels at Low Temperatures

By G. I. POGODIN-ALEXEYEFF and A. V. PAMFILOFF. (From *Stanki i Instrument*, No. 4, 1951, pp. 22-23, 3 illustrations.)

The authors' report on investigations into the influence of surface roughness on impact strength at room and subzero temperatures. All criteria expressing toughness are improved with smoother machining ; this applies, in particular, to strength under repeated impact. This tendency is more noticeable with hard steels than with soft steels.

THE influence of surface roughness on static and fatigue strengths has been investigated fully by N. N. Davidenkoff, S. V. Sorensen and others. An improvement in surface smoothness increases the static strength as well as the endurance limit of steel. The influence of surface smoothness on impact strength has not been sufficiently examined. E. M. Shevandin has established that the condition of the surface inside the notch does not influence the critical temperature range of cold brittleness. However, the zone of plastic deformation of the test specimen following the impact usually greatly exceeds the extent of the notch, and the surface smoothness in the zone of plastic deformation, particularly in unnotched test specimens, must, in our opinion, have some influence on impact strength and the threshold of cold brittleness in steel.

The authors have investigated unnotched test specimens made of steel St 5* and steel St 3† of cylindrical shape, 8 mm in diameter and 75 mm in length, and also cylindrical test pieces of 10 mm diameter, their length being equal to that of the former specimens, but with a spherical notch extending along a length of 4 or 7 mm in the middle of the test specimen and having a depth of 2 mm (on radius). Surface machining of the test specimens was carried out to smoothness class 3, 9, and 11, in accordance with Russian standards. Furthermore, for comparison, test specimens with rough-machined surfaces having a maximum peak-to-valley height of 100-200 microns were also tested. This roughness is beyond the range of the above standard specifications and is arbitrarily denoted by zero smoothness.

Single impact tests at room temperature, on a pendulum-type impact machine, on test specimens having a notch length of $l_0 = 4$ mm and made of steel St 5 have shown the following impact energies (mean of 10 test specimens) :—

Class 11	smoothness	3·04	kgm
,, 9	,,	2·95	,,
,, 3	,,	2·68	,,
,, 0	,,	2·59	,,

*0·28–0·37 C, 0·5–0·8 Mn, 0·17–0·35 Si, 0·55 S, 0·5 P.
†0·14–0·22 C, 0·35–0·60 Mn, 0·12–0·35 Si, 0·55 S, 0·5 P.

TABLE I. NUMBER OF BLOWS TO DESTRUCTION IN TESTS WITH REPEATED IMPACT ON CYLINDRICAL TEST SPECIMENS OF VARYING SURFACE SMOOTHNESS.

Type of test specimen	Class of Smoothness	Number of blows to destruction for an impact energy in kg/cm.				
		2·08	6·0	23·45	52·16	93·78
Cylindrical with notch of $l_0 = 7$ mm steel St 5	0	2802	302	17	3·6	1
	3	3402	380	23	4·0	1·4
	9	3821	437	24	4·3	1·7
	11	3854	453	28	5·2	2
same with $l_0 = 4$ mm steel St 5	0	701	120	13	4·0	1·5
	3	854	151	15	4·3	1·7
	9	962	184	17	4·5	2
	11	1097	195	19	5·0	2
same with $l_0 = 7$ mm steel St 3	0	6210	952	82	19	6
	3	7502	1118	95	22	8
	9	8497	1222	101	24	9
	11	8995	1486	112	28	10·3

Thus, the increase in impact strength caused by improvement in surface smoothness was not great in this case and did not exceed 17 per cent.

For determination of the threshold of cold brittleness and the temperature margin of toughness, which are more important and more sensitive criteria, the test specimens were tested at progressively reduced temperatures. The results of these investigations are shown in the graphs of Figs. 1 and 2, the numerals denoting the class of surface smoothness.

Repeated impact tests at room temperature were carried out on the same pendulum impact machine. The test specimens were placed on their supports and subjected to successive blows with a given amount of stored impact energy. The strength criterion was the number of blows to destruction. The results of the tests are shown in Table I (mean of three specimens of each type) and, for one of the batches of test specimens (notch of $l_0 = 4$ mm, steel St 5), these results are shown graphically in Fig. 3.

CONCLUSIONS

1. Surface smoothness has a substantial influence on the resistance of parts to impact stresses, both single and repeated.

2. With an increase in the degree of smoothness, the impact strength of steel is raised

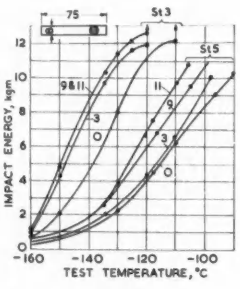

Fig. 1. **Influence of surface smoothness of cylindrical unnotched test specimens on cold brittleness of steels St 3 and St 5.**

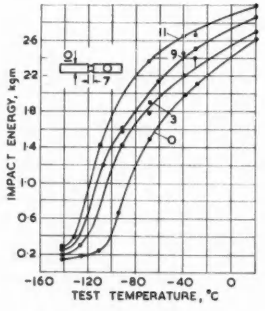

Fig. 2. **Influence of surface smoothness of cylindrical test specimens with a notch of $l_0 = 7$ mm on the cold brittleness of steel St 5.**

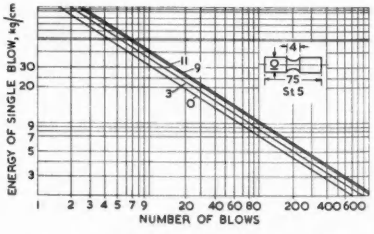

Fig. 3. **Influence of surface smoothness on the strength under repeated impact blows.**

somewhat and the critical temperature of cold brittleness is displaced towards lower temperatures by 12-15° C in unnotched specimens and by 30-40° C in cylindrical specimens with a notch length $l_0 = 7$ mm. This fact can be taken as evidence of a reduced sensitivity of smoothly machined parts to notch effects and changes of section, speed of deformation, size factor, etc.

3. The beneficial influence of surface smoothness is more pronounced in tests by repeated impact. The number of blows required for the destruction of specimens machined to class 11 smoothness is, on average, 1·5 times greater than the number required in rough-machined specimens (class 0).

4. There is an optimum degree of surface smoothness which ensures a noticeable increase of resistance to destruction by impact (while satisfying requirements of economy and simplicity of machining). Under the conditions of the tests carried out, the optimum smoothness is that of class 9 standard. Further improvements in smoothness is less effective and extremely difficult to achieve.

5. The effect of surface smoothness is more sharply evident in steel St 5 than in steel St 3 ; it is more noticeable with hard steels than with soft steels.

U.S.A.

Boron Steels in the Present Emergency

By P. R. Wray. (From *Steel*, Vol. 129, No. 1, July 2, 1951, pp. 78-82, 8 illustrations.)

The hardenability of a new series of constructional steels containing Boron matches that of steels containing rarer alloying elements, and these new steels are expected to replace 70 to 80 per cent of the constructional alloy steels used at present.

The shortage of alloying elements such as cobalt, tungsten, molybdenum and nickel for other than military applications is causing a search for other, more readily available, elements with similar alloying properties. Recent production tests in the U.S. have shown that boron can replace a substantial portion of nickel, chromium, molybdenum and other critical elements where their presence is necessary only for adequate hardenability.

Boron as an alloying element has other advantages as well, such as improved hot and cold working, and a shorter annealing cycle and improved machinability, all of which should result in economies.

While the potentialities of boron steels were recognised as early as 1907, only during the latter part of the second World War did their use in larger quantities begin. Since 1945, boron steels have been used in several large production applications, replacing higher-alloy steels at a considerable saving in the cost of both steel and fabrication.

Increased Hardenability. Boron can replace several hundred times its own weight of other hardening alloys such as manganese, chromium, molybdenum and nickel. The effect of boron on hardenability decreases with increasing carbon content (see Fig. 1) ; thus, boron is more effective in the conservation of critical alloys in the lower-carbon steels.[1]

Isothermal Transformation Behaviour. Isothermal transformation diagrams are helpful in understanding the behaviour of boron steels during heat treatment. Fig. 2 shows steel 1345 plus boron against steel 4140 containing no boron. The time for beginning of transformation at the "nose" is approximately the same for both (indicating equivalent hardenability), while the time for completion is much shorter for steel 13B45.

Boron as an alloying element is unique in that it delays the start of the transformation appreciably, while delaying completion only slightly. Thus, a lower-alloy steel containing boron can have the same properties as a higher-alloy steel, when hardened, yet the boron steel can be annealed with a much shorter cycle. Such steels are also softer than the higher-alloy steels in the normalised condition, provided air quenching does not occur.

Effect on Ae_1, Ae_3 and M_s Temperatures. Boron has apparently little effect on the Ae_1, Ae_3 and M_s temperatures of the base composition. It tends to lower the austenite coarsening temperature of a steel, but this tendency can be counteracted by an increase in the aluminium addition used for grain size control.

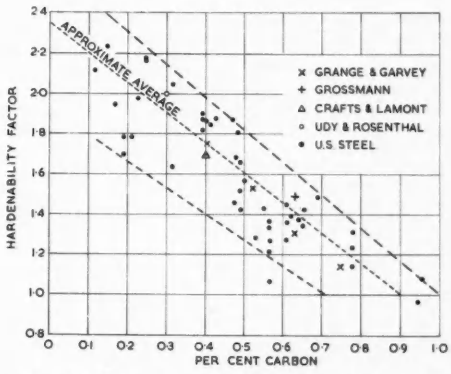

Fig. 1. **Effect of carbon content on hardenability factor for boron based on ideal critical diameters derived from 50 per cent martensite critical hardness.**

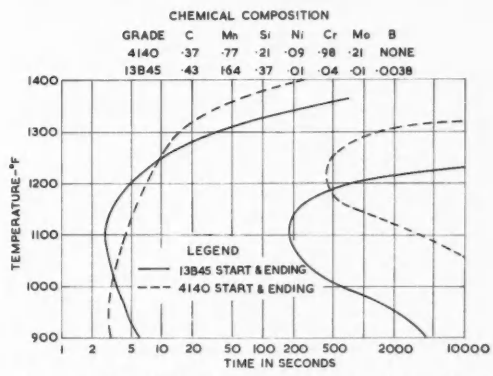
CHEMICAL COMPOSITION
GRADE C Mn Si Ni Cr Mo B
4140 ·37 ·77 ·21 ·09 ·98 ·21 NONE
13B45 ·43 1·64 ·37 ·01 ·04 ·01 ·0038
TEMPERATURE-°F
TIME IN SECONDS
LEGEND
13B45 START & ENDING
4140 START & ENDING

Fig. 2. **Isothermal transformation in the pearlite region of steels 4140 and 13B45.**

Notch Toughness. The effect of boron on notch toughness is not clear at present. The notch toughness, however, remains adequate for most engineering applications. Endurance limit and endurance ratio are the same for a given hardness as in other alloy steels treated to the same hardness.

Tempering Behaviour. When boron is used in place of other alloying elements, it is usually necessary to use a lower tempering temperature to obtain a given hardness and strength. It is advisable to use pilot tests to determine this temperature. The tensile strength will be the same at the same tempered hardness. Since boron apparently does not retard softening appreciably during tempering, boron steels are not expected to replace molybdenum, vanadium or tungsten alloy steels for high-temperature service.

It is essential that the hardenability of the boron steel be sufficient to obtain martensite prior to tempering, so that optimum properties can be developed at the location where the highest stresses are encountered.

Hot and Cold Working, Annealing and Machining. Little mention has so far been made in the literature of the very desirable processing characteristics of boron steels, such as forgeability and ease of cold-heading, de-scaling, annealing and machining. It has been reported[2] that boron steels have a lighter and less adherent scale, require less pickling, and increase die life by as much as 25 per cent in comparison with equivalent non-boron steels. Annealing time and costs were halved by changing to the boron steel, and machinability was also improved.

Properties in Carburizing. Research has been devoted in recent years to finding a steel of good hardenability and absence of retained austenite and undissolved carbides after carburizing and hardening. The steel eventually developed contained boron and 0·03-0·07 per cent vanadium. This development was then extended to lower-alloy steels. The work over the last four years has shown that lower-alloy steels containing boron will have the same core properties as the higher-alloy steels which they match in hardenability, and at the same time are easier to forge, anneal, machine and to heat-treat after carburizing, because of their lower total alloy content.

Hardenability of the Carburized Case. Fig. 3 shows how the effect of boron on hardenability decreases with increasing carbon content, in a high-manganese carburizing steel (1321). It is seen that, above 1 per cent carbon content, boron effects no improvement. It is, therefore, necessary to limit the carbon content of a boron steel case intended to replace a higher-alloy steel.

Apparent Loss in Core Hardenability on Direct Quenching following Carburizing. It was reported[3] that heating to high temperatures sometimes resulted in a partial or complete loss of the hardenability effect of boron. This loss was also found in boron carburizing steels after long periods of heating at carburizing temperatures followed by direct quenching. Fig. 4 shows how increase in temperature lowers the hardenability. In Fig. 5, the curve for the sample pseudo-carburized at 1750° F is re-plotted along with one obtained by the normal treatment of 20 minutes at 1700° F followed by quenching; the third curve was obtained by pseudo-carburizing 17 hours at 1750° F, slow cooling to 1550° F (equalising), followed by quenching. It is noteworthy that the loss in hardenability is recovered by the slow cooling to 1550° F prior to quenching. The mechanism of this phenomenon is not yet known.

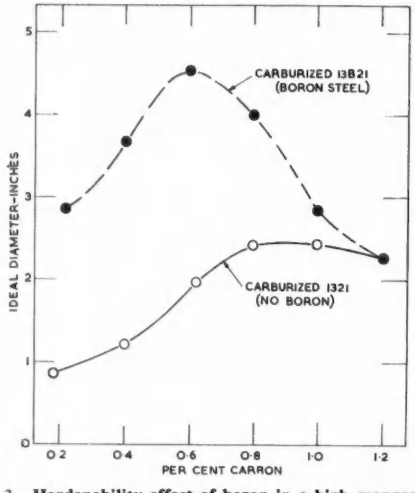

Fig. 3. **Hardenability effect of boron in a high manganese carburizing steel.**

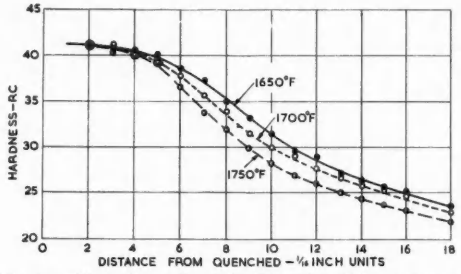

Fig. 4. **Effect of pseudo-carburizing for 17 hours at each indicated temperature upon the hardenability of an 86B20 steel (0·18C, 0·83 Mn, 0·49 Ni, 0·49 Cr, 0·19 Mo, 0·0013 B).**

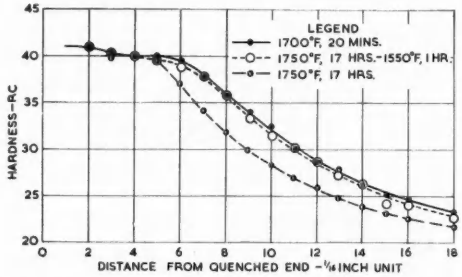

Fig. 5. **End quench hardenability tests of steel 86B20.**

New boron constructional alloy steels. The American Iron and Steel Institute, in February 1951, announced two new series of steels designed for conserving the critical alloying elements. The steels, known as 80Bxx and 81Bxx, are low-nickel, chromium, molybdenum compositions containing boron, in which the boron has replaced about half of the critical alloy content of mass production steels hitherto employed. Three other boron steel types are at present showing promise in the replacement of high-alloy carburizing steels.

It is expected that these steels will be able to replace 70 to 80 per cent of the present constructional alloy steels on an equivalent hardenability basis. The Society of Automotive Engineers has established a special division to collect and disseminate the experience gained in the production, fabrication, testing and use of the new steels.

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(1) G. D. Rahrer and C. D. Armstrong: Effect of Carbon Content on Hardenability of Boron Steels. *Trans. A.S.M.*, Vol. 40, 1948, pp. 1099-1123.

(2) F. J. Robbins and J. J. Lawless: Use of Boron Steel in Production. *Metal Progress.*, Vol. 57, No. 1, Jan. 1950, pp. 81-89.

(3) R. A. Grange and T. M. Garvey: Factors affecting the Hardenability of Boron-treated Steels. *Trans. A.S.M.*, Vol. 37, 1946, pp. 136-191.

Centreless Bar Turners and Billet Peelers

By W. REICHEL. (From *Stahl und Eisen*, Vol. 71, No. 4, February 15, 1951, pp. 183-193, 38 illustrations.)

Despite many attempts to replace the usual machining operations by cheaper chipless methods of working, "bar-peeling" has in fact become an indispensable semi-finishing process. While cutting operations such as turning, milling, and shaping have been thoroughly investigated, the peeling process has been neglected, although it is one of the most economical cutting operations.*

FIELD OF APPLICATION

WHILE peeling machines are single-purpose machines for the working of bars and tubes, they have many uses for the manufacture of semi-finished products, such as transmission shafting. In contrast to cold-drawn shafting, peeled shafts are free from internal stresses, grooves, and acid-inclusions (as no pickling is necessary) and there is no difference in strength between surface and core. Production costs are less than those for cold-drawing. Shafts of more than 60 mm (2⅜ in.) dia. and of high tensile strength cause difficulties in drawing and should be peeled.

Round Bars for Use on Automatics, Capstan Lathes, etc. Grip of cutting tool better than on cold-drawn bars. No troubles caused by scale; closer initial tolerances. Shorter setting-up, maintenance and cutting times.

Ball-bearing Steels. Peeled bars are specially suited for this purpose, enabling the quick detection of all surface faults.

Materials Testing. Detection of cracks, sand inclusions, etc., on peeled billets.

Steelworks. Peeling of rolled billets instead of turning of ingots to smaller diameters.

Tube Mills. Peeling of billets for the production of seamless tubes, in order to detect flaws in the material. Preparation of new mandrels or turning of used ones to smaller diameters.

Substitute for Ground Shafts. Cheaper than centreless grinding. Simultaneous application of polishing heads ensures a surface smoothness not inferior to grinding.

THE PEELING PROCESS

Peeling consists of a centreless turning operation on long rods of circular cross-section where the cutting head revolves around the material, at the same time guiding and feeding it through, see Fig. 1. The object of peeling is :—

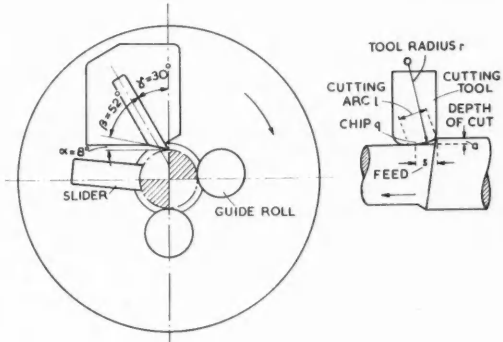

Fig. 1. The peeling process.

(1) Removal of scale and prevention of decarbonised outer layer as occurs in rolled or forged material.
(2) Achievement of close tolerances on diameter.
(3) Production of smooth surfaces. This yields the following advantages :—
(1) A surface suitable for further working.
(2) The elastic properties of the material remain unchanged.
(3) No preliminary operations such as pickling and scaling are necessary.
(4) The peeled material is free from internal stresses.
(5) The centreless operation eliminates any tool-chatter.
(6) The shape of the peeling tool allows a cutting speed far in excess of that possible with normal turning between centres.
(7) Bars do not have to be straightened to the same extent as for turning (e.g., a deflection of 20 mm (13/16 in.) on a length of 5-7 metres (16-23 ft) is still permissible).
(8) Considerably smaller loss of material than with turning, see Fig. 2.

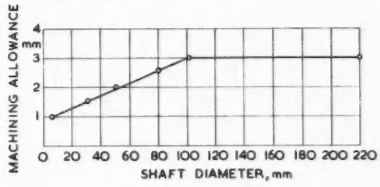

Fig. 2. **Graph showing machining allowance as a function of diameter.**

PEELING AND GUIDING HEADS

The large radius of the cutting tool (Fig. 1) produces a high degree of surface finish. Smooth operation results from the varying thickness of the shavings, thus avoiding resonance between the vibrations due to cutting and feeding pressure. The front part of the tool cuts the thinnest cross-section of the chip, and the life of the tool is thus prolonged. Due to the longer arc of contact between tool and material, the heat is dissipated more efficiently.

The rake of the cutting tool and the composition of the tool steel will depend on the material to be worked. High-speed steels are used in general, while carbide tools are less suitable because of the large feeds per revolution (up to 16 mm) and slow cutting speeds (up to 40 m/min) employed.

A further problem is the gripping and adjustment of the peeling tools. Peeling produces short chips which are carried around in the cutting head and may cause obstruction and scratch the surface. Thus, the cutter must be provided with guides which strip off the chips while at the same time sliding over the surface with little friction. Rollers and sliding guides both have their advantages and the two may be suitably combined. The usual type of roughing head has one cutter only. The slide behind the cutter is used for the removal of chips, and the two rollers serve as supports. Fig. 3 shows another solution, where sliders are used in the cutting plane, and rollers are used in a separate guiding head mounted adjacent to the cutter head. The adjustment of the knife and supports is done by means of mandrels outside the machine. The question

*The German "schälen," translated here as "peeling," indicates a centreless cutting operation, and "peeling" will be used in this sense throughout the article. American practice distinguishes between centreless turning (light cut) and peeling (heavy, deep cut). *Editor, E.D.*

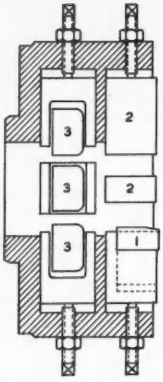

Fig. 3. **Finishing head with separate roller steady box.**
(1) = peeling tool, (2) = sliding guides, (3) = roller guides.

of the most suitable material for the guide elements requires further investigation, especially as it affects the possibility of higher cutting speeds and, thus, the employment of carbide tools. Moreover, a higher cutting speed would be desirable for the finishing cut to improve the surface finish, whereas at present the two heads are mounted on the same spindle and thus revolve at the same speed.

Cutting Speeds

The factors which determine cutting speeds in peeling are different from those which apply to turning. An upper limit to cutting speed is set by the friction of the sliding guides and by the time required for the removal of the chips. Usual cutting speeds vary between 10 and 40 metres per minute (33 and 131 fpm). Fig. 4 shows the author's investigations into the influence of the strength of materials on cutting speeds, the adjoining diagram giving the required cutter head speed in rpm for a given diameter of bar.

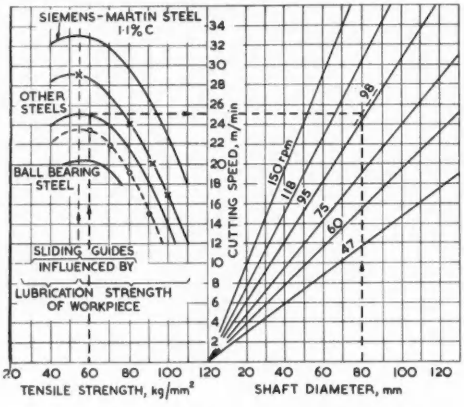

Fig. 4. **Cutting speed diagram for peeling machines.**

According to American experience, the most economical cutting speeds for a given material are obtained for diameters of about 100 mm (4 in.) and fall off with increasing or decreasing diameter. The nomogram in Fig. 5 gives the relationships between tensile strength, diameter and cutting speed.

The appropriate cutting speeds must be realised by suitable control of the rotational speeds of the machine. Fig. 6 gives the range of speeds on two typical German machines and an American machine with a capacity of 40 to 130 mm (1½ to 5⅛ in.) dia. The differences between the three machines are clearly noticeable—an indication that standardisation in this field will be difficult to achieve, owing to the wide variety of different cutter heads, tool-forms and quality, materials, surface finish, etc., presenting problems which can only be settled on the basis of workshop experience.

Feed and Output

The relation between feed and diameter shows similar lack of uniformity; Fig. 7 indicates that American

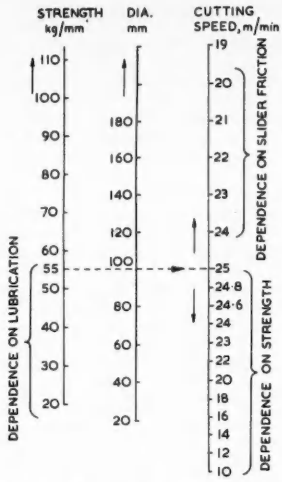

Fig. 5. **Nomogram for cutting speed determination.**

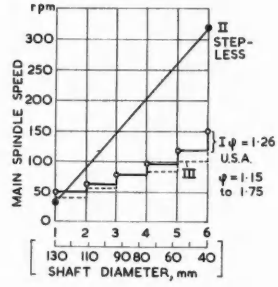

Fig. 6. **Examples of change wheel ratios employed by various manufacturers.**

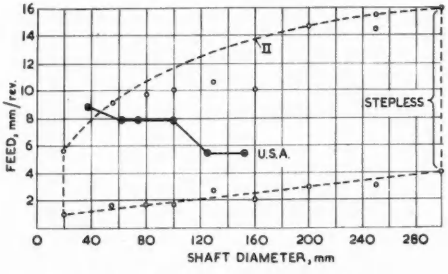

Fig. 7. **Feed ranges of peeling machines.**

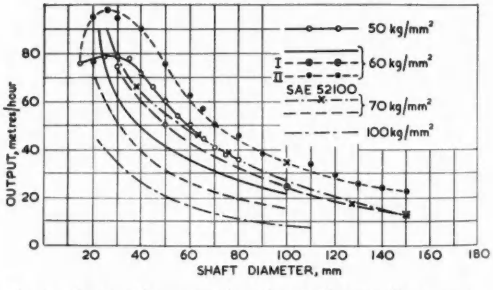

Fig. 8. **Output figures as given by peeling machine manufacturers and steel makers.**

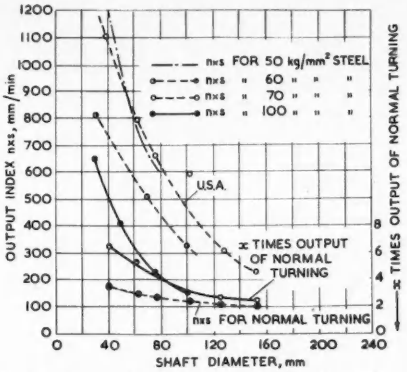
OUTPUT INDEX nxs, mm/min
nxs FOR 50 kg/mm² STEEL
nxs " 60 " " "
nxs " 70 " " "
nxs " 100 " " "
U.S.A.
x TIMES OUTPUT OF NORMAL TURNING
nxs FOR NORMAL TURNING
x TIMES OUTPUT OF NORMAL TURNING
SHAFT DIAMETER, mm

Fig. 9. **Comparison between peeling and turning.**

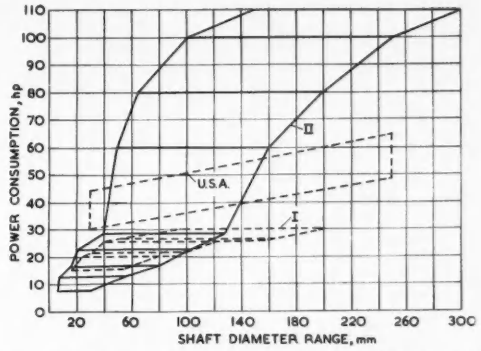

Fig. 12. **Range and power consumption of peeling machines of various makes.**

practice employs a smaller feed with larger diameters, while German practice shows a contrary tendency. A more uniform picture is afforded by the output figures of a number of peeling machinery manufacturers and steel producers, as shown in Fig. 8.

The high output figures of the peeling process are mainly due to the very much larger feeds employed (up to 16 mm per revolution) than in ordinary turning (0·1 to 1·7 mm). Even more impressive is the comparison between the values of the "index figure" ($n \times s$ = rpm × feed) for peeling and turning, this index figure being 2·3 to 6·6 times greater for peeling. Fig. 9 shows a plot of the index figure for various steels against bar diameter.

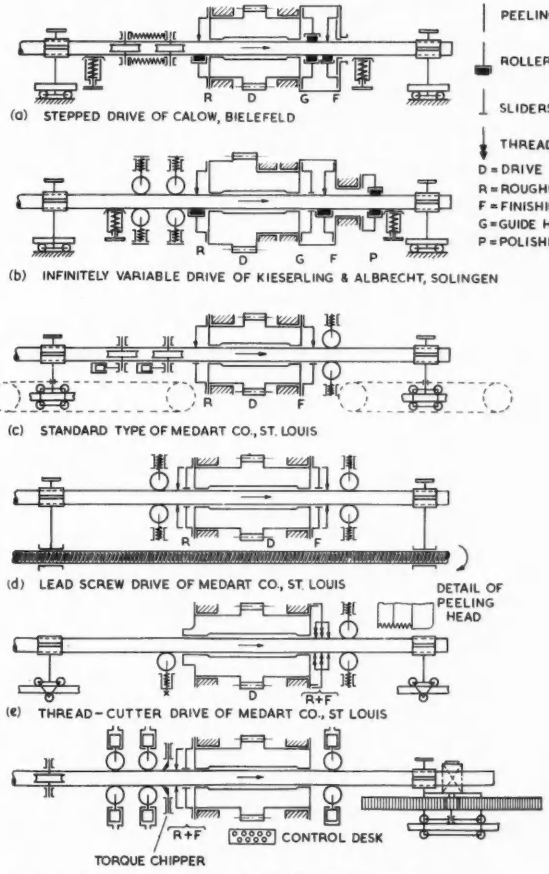
PEELING TOOL
ROLLER GUIDES
SLIDERS
THREAD CUTTER
D = DRIVE
R = ROUGHING HEAD
F = FINISHING HEAD
G = GUIDE HEAD
P = POLISHING HEAD
(a) STEPPED DRIVE OF CALOW, BIELEFELD
(b) INFINITELY VARIABLE DRIVE OF KIESERLING & ALBRECHT, SOLINGEN
(c) STANDARD TYPE OF MEDART CO., ST. LOUIS
(d) LEAD SCREW DRIVE OF MEDART CO., ST. LOUIS
DETAIL OF PEELING HEAD
(e) THREAD-CUTTER DRIVE OF MEDART CO., ST LOUIS
CONTROL DESK
TORQUE CHIPPER
(f) PUSH-BUTTON CONTROLLED DRIVE OF MEDART CO., ST. LOUIS

Fig. 13. **Schematic representation of different machine types.**

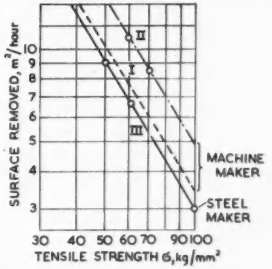

Fig. 10. **Surface removed in peeling as function of tensile strength.**

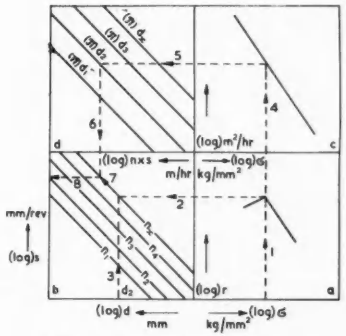

Fig. 11. **Speed and feed nomogram.**

Combined Speed and Output Determination

A more general picture of the output of peeling machines is obtained by calculating the surface worked for different materials and diameters. From the (hyperbolic) curves of Fig. 8, this yields the diagram of Fig. 10, indicating that a fixed value of the surface areas removed cor-

mainly due to the very much larger feeds employed (up to 16 mm per revolution) than in ordinary turning (0·1 to 1·7 mm). Even more impressive is the comparison between the values of the "index figure" ($n \times s$ = rpm × feed) for peeling and turning, this index figure being 2·3 to 6·6 times greater for peeling. Fig. 9 shows

responds to a given tensile strength for a given machine.

From an output curve of Fig. 10 the diagrams of Fig. 11 can be constructed so that :

(1) From the nomograms *a* and *b* (constructed on a logarithmic scale from Fig. 4), the economical speeds (along the arrows 1, 2, 3) can be found, and

(2) from the surface area a nomogram *c* and the conversion nomogram *d* for the output in metres/hour (along arrows 4, 5, 6), finally, the required feed *s* can be found (along arrows 7, 8).

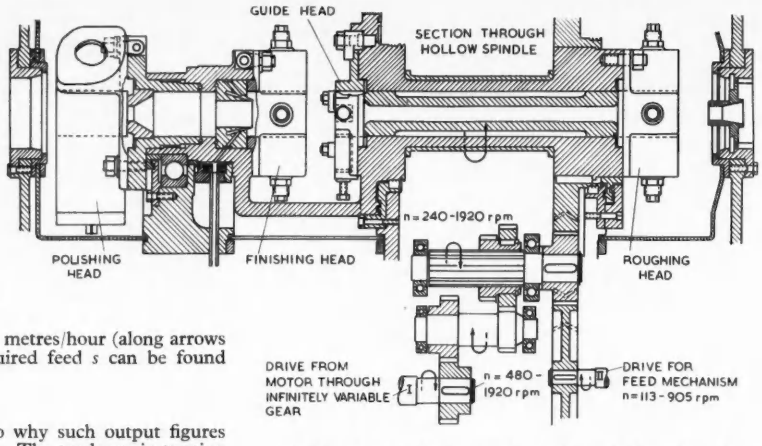

Fig. 14. **Section showing main spindle and drive of machine type shown in Fig. 13b.**

Power Consumption

The question arises as to why such output figures cannot be reached in turning. The tendency in turning has been, with the use of hard metal tools, to reduce the feed, in order to ensure good heat conduction through increasing the ratio $\frac{\text{depth of cut}}{\text{feed}} = \frac{a}{s}$ which also results in a better surface finish. This ratio is appreciably lower for peeling (e.g., 0·2 as compared with 5·5 for turning). As is well known, the cutting pressure and, therefore, the power consumption decrease with a decreasing ratio a/s. For equal cross-sections of material removed, peeling could thus be expected to have a lower power consumption. However, the larger radius of the cutting tool necessitates higher pressures, probably cancelling out this advantage.

No investigation of this problem of cutting pressures in peeling is known to have been made. Thus, for data on power consumption one has to fall back on the experience of individual firms. Fig. 12 gives the driving power employed by two German firms and an American firm for machines of various ranges. The large differences for capacities above 130 mm (5⅛ in.) dia. are especially noteworthy.

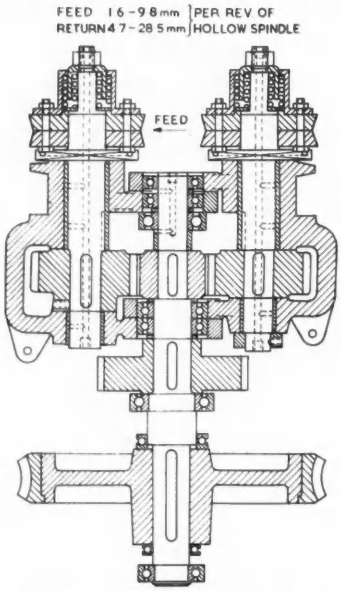

Fig. 15. **Feed drive of machine type shown in Fig. 13b.**

Types of Peeling Machinery

Fig. 13 gives a schematic representation of a number of different types of peeling machines in current use :—

(a) shows a construction often employed. It includes a positive feed and roughing, guide and finishing heads. The imput carriage on to which the bars are clamped is provided with a safety stop to guard against the possibility of collision with the machine frame if the clamp is not released in time.

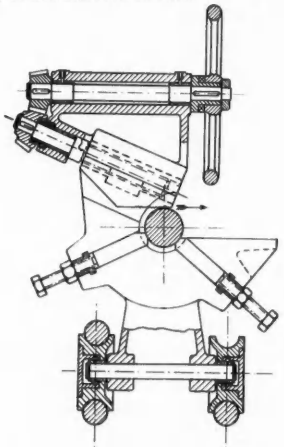

Fig. 16. **Carriage of machine type shown in Fig. 13b.**

(b) is also a form often used. Feed and speed are infinitely variable while the machine is in operation. Fig. 14 is a cross-section of the peeling-head and hollow spindle drive, while Fig. 15 shows the feed drive. The bearing arrangement between the finishing head and polishing attachment allows a stream of coolant to reach the work-piece at that point.

At each side of the machine, the carrier rails can accommodate bars up to 8 metres (26 ft) long. The carriages are illustrated in Fig. 16.

(c) In this type, the feed-rollers are operated

(*Concluded on page* 314)

CLASSIFIED ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns, are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

ELECTRONICS

The Cesium-Vapour Rectifier

By A. W. HULL, E. E. BURGER and R. E. TURRENTINE. (From *General Electric Review, U.S.A.*, Vol. 54, No. 8, August, 1951, pp. 16-22, 14 illustrations.)

THIS is a new type of hot-cathode vapour rectifier, in which cesium-vapour functions both as conducting gas and thermionic coating material. The cathode is of the conventional type used in thyratrons, namely, a multicellular structure of nickel vanes, surrounded by a heat shield. However, it differs from conventional cathodes in that the vanes are uncoated except by the monatomic film of cesium which is continually reformed by condensation. The tube must be heated to approximately 160-180° C during operation, to maintain the desired vapour pressure of 0·015-0·035 mm.

Cesium is unique in having the lowest ionization potential and the lowest thermionic work function of any known element. Hence, one was led to expect optimum efficiency from this dual use of cesium. This expectation has now been realised, the over-all efficiency at 250 volts being better than 98 per cent for the tubes tested. Typical values are: cathode heating power, 280 watts; peak electron emission, 2800 amp; voltage drop at 600 amp, 3·30 volts.

The tests described prove that the low voltage drop and high electron emission which are characteristic of cesium can be utilised in gaseous rectifiers to give high efficiency and reliable operation. The results indicate that, with proper design, cesium rectifiers and thyratrons can be built for any desired currents and for voltages at least as high as 300.

Two design features requiring special attention are electric leakage over ceramic insulators in cesium vapour and the effects of magnetic field. It is believed that cesium-resistant ceramic materials can be found which will obviate the leakage problem. The effect of magnetic field merits further study. But it is to be noted that this effect was observed when *large* currents were crowded into a *small* tube, and hence it probably can be avoided by proper design; it was inappreciable at current densities such as those used in conventional mercury-vapour tubes. Such magnetostrictive effects are not to be expected in cesium tubes of high current rating if they are housed in envelopes of appropriate size, namely, a size comparable to that of mercury tubes of similar rating.

FOUNDRY PRACTICE

Pouring Time and its Relation to the Solution of Gating Systems

By J. KIESWETTER. (From *Hutnické Listy, Czechoslavakia*, Vol. 6, January, 1951, pp. 14-22, 24 illustrations.)

IN the first part of the paper, the general conditions which arise during pouring of the liquid metal into the mould are reviewed. Following this, the various factors affecting the pouring time are mathematically analysed and, on the basis of thermodynamic laws, formulae are derived for calculation of the pouring time and the dimensions of the gating system for grey iron castings. The application of these formulae is shown by calculation of various examples of gating systems. The author has also worked out a table of pouring times of grey iron castings weighing 22 lb to 40 tons with wall thicknesses ranging from $\frac{1}{8}$ to $1\frac{1}{8}$ in. The formula derived by the author differs from that proposed by H. W. Dietert for calculation of pouring times, and this is due to the fact that in the Dietert formula the process of gradual filling-up of the mould has not been taken into consideration.

INTERNAL COMBUSTION ENGINES

The Utilization of Exhaust-Gas Energy in the Supercharging of the Four-Stroke Diesel Engine

By E. JENNY. (From *The Brown Boveri Review, Switzerland*, Vol. 37, No. 11, November, 1950, pp. 433-447, 14 illustrations.)

IN order further to develop the technique of turbocharging, a very thorough study of the engine exhaust process has been undertaken. The rules which should be observed in order to obtain the best use of the available exhaust gas energy, combined with the minimum of losses, are indicated. Of the greatest importance is the reduction of the throttling losses in the exhaust valve during the initial exhaust period, i.e., the period between the opening of the exhaust valve and the attainment of maximum value by the pressure wave thus released. The length of the exhaust pipe also plays an important role. It is shown that with certain pipe lengths, satisfactory performance cannot be obtained. The cross-section of a long pipe should not be substantially greater than that of the fully open exhaust valve passage, and for this reason it should be ensured that the exhaust valves open as quickly as possible.

In order to verify the theory, a test installation was set up using a model exhaust system. Exhaust processes are similar if the dimensionless coefficients introduced agree with one another. When making tests with models, using cold air, exact similarity cannot be ensured for the various less important influences such as heat conduction, temperature gradients and the isentropic exponent. Nevertheless, the carrying out of simple tests, not dependent upon the engine, produces the essential results.

Mention is also made of recent advances in the turbocharging of two-stroke Diesel engines, where the control of exhaust conditions is most important.

IRON AND STEEL

885° F Embrittlement of the Ferritic Chromium-Iron Alloys

By J. J. HEGER. (From *Metal Progress, U.S.A.*, Vol. 60, No. 2, August, 1951, pp. 55-61, 7 illustrations.)

THE 885° F embrittlement of the ferritic stainless steels is characterised by an increase in hardness, tensile strength, and yield strength, and by a decrease in ductility and impact strength. Changes in electrical resistance, density, magnetic properties and corrosion resistance also occur. These changes in mechanical and physical properties occur after the steels have been heated in the temperature range of 700 to 1000° F, and have been observed in tests made at room temperature and in tests made at the embrittling temperature.

Precipitation of one or more constituents has accompanied these changes in physical and mechanical properties. However, a positive identification has not

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been made by analysis of X-ray diffraction spectra except when specimens drastically cold-worked prior to embrittlement were used. In such specimens, the precipitate has been identified as sigma phase (iron-chromium compound).

Neither additions of alloying elements, variations in heat treatment, nor elimination of impurities have prevented these gradual changes in the hot alloy.

For pure iron-chromium alloys, the embrittlement is believed to be caused by the precipitation of sigma phase (or some transitory phase that precedes the formation of sigma). In commercial iron-chromium alloys, the precipitate that forms during heating in the range of 700 to 1000° F may include nitrides, phosphides, and carbides, as well as sigma.

MACHINE TOOLS

Providing Tools with Chip Breakers by Spark Machining

By L. Kocsis. (Originally published in *Magyar Technika, Hungary*, No. 7, July 1950, pp. 6-10, abstract from *Hungarian Technical Abstracts*, No. 4, 1951, p. 7.)

With the development of high-speed machining using negative rake angle cutting tools, the employment of chip breakers is of growing importance. Machining chip breaker grooves into the cutting edges of high-speed steel, especially carbide tools, by conventional methods requires relatively large quantities of grinding wheels and takes a great deal of time as well. The Hungarian Stakhanovites, on their return from a recent visit to several factories in the Soviet Union, explained to the technicians the methods and equipment used in the Soviet factories for producing chip breakers by spark machining. Utilizing the experiences of the Stakhanovites, the engineers at the *Mátyás Rákosi-Works* conducted experiments to establish the suitable current, electrodes and cutting coolants. On the basis of the tests made, the first ten of a series of machines for spark machining high-speed steel tools and carbide tools were completed. With these machines, high-speed steel tools can be provided with chip breakers within 15 to 30 seconds and carbide tools within 30 to 60 seconds.

METALLURGICAL ENGINEERING

An Introduction to Arc-Cast Molybdenum and Its Alloys

By J. L. Ham. (From *Transactions of the ASME, U.S.A.*, Vol. 73, No. 6, August, 1951, pp. 723-732, 16 illustrations.)

The advantages and limitations of the arc-casting method for producing metallic molybdenum and its alloys are discussed. The general properties of unalloyed cast molybdenum are described and curves are presented to show the room temperature tensile properties, hardness, and notched-bar values after annealing at various temperatures, the effect of testing temperature on hardness, and the transition temperatures for various types of impact tests.

The need for addition of alloying elements is discussed. Preliminary selection of appropriate alloying elements was based on their vapour pressures and known or expected solubility limits. Curves are presented showing the solid solubility limits of silicon, aluminium, iron, cobalt and nickel in molybdenum at various temperatures as determined by the measurement of lattice parameters of arc-cast samples, and the effects of beryllium, aluminium, silicon, titanium, vanadium, chromium, iron, cobalt, nickel, zirconium, columbium, tantalum, and tungsten on the hardness of molybdenum at various temperatures. Molybdenum containing a small amount of beryllium can be hardened by quenching and softened by slow cooling.

Regardless of which alloying element is used, there appears to be a limit to the increase in hardness that can be tolerated without causing difficulty in hot-working by the techniques applied so far.

The effects of several of the alloying elements on the rate of work-hardening and on the temperatures of softening, and recrystallisation were studied, using a series of alloys which were extruded.

PLATING

Thin, Attractive Metal Coatings Produced by Vacuum Method

By K. Rose. (From *Materials & Methods, U.S.A.*, Vol. 33, No. 6, June, 1951, pp. 71-73, 4 illustrations.)

Several methods can be used for developing a metallic surface on a non-metallic material; the simplest of these methods is the vacuum evaporation process. The metal usually used is aluminium, which can easily be vaporised, but other metals such as gold, silver, chromium, zinc and Inconel also lend themselves to this process.

The equipment consists of a container for the work, which can be a bell jar for a small unit, or a metal vacuum chamber for larger installations; vacuum pumps, usually of the diffusion type, to exhaust the air from the container to a vacuum of one-tenth of a micron of mercury; one or more electrodes holding the heaters or filaments used to evaporate the coating metal; and the necessary power supply and control gauges. Special devices, such as heaters for continuous vaporising of metal, and a winding mechanism to permit rolling and unrolling of strips of stock during continuous coating, can also be a part of the machine. Special trays or racks to hold the pieces to be coated to best advantage can also be used.

The coatings produced require no additional finishing by hand. They are extremely thin and have only decorative but no protective value. The vapour travels in straight lines and the work must therefore be carefully arranged for coating.

The vacuum coating process is widely used for metallising plastics, e.g., motor car trim, novelty items, etc. Paper has been coated with aluminium by vaporising to produce a wrapping material as a substitute for the expensive laminated paper foils. Work has been done on the metallising of cloth to provide heat reflectivity.

THERMODYNAMICS

A Study of the Mechanism of Boiling Heat Transfer

By W. M. Rohsenow and J. A. Clark. (From *Transactions of the ASME, U.S.A.*, Vol. 73, No. 5, July, 1951, pp. 609-620, 10 illustrations.)

An analysis of the heat quantity required to form a vapour bubble in a liquid is presented. High-speed motion pictures of boiling heat transfer in forced convection showing bubbles departing from a heated surface are analysed and the net heat transferred to the bubbles is compared with the total heat transferred from the heated surface. It is found that the heat transferred to the moving liquid by the condensation of the bubbles is a negligible part of the total convective heat transfer. Therefore, it is proposed that the high rate of heat transfer associated with surface boiling in a sub-cooled liquid is due primarily to the violent agitation of the quiescent layers of liquid adjacent to the heated surface resulting from the motion of vapour bubbles being generated there. From the literature two examples of similar processes are cited as evidence supporting the proposed agitation mechanism.

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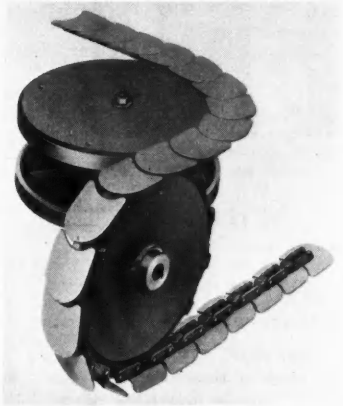
New Materials, Processes and Equipment

NEW CONVEYOR CHAIN

A new flat top conveyor which flexes in two planes—both horizontally and vertically—and can curve around corners with a radius of as little as 6 inches with ease, is now being marketed by Chain Belt Co. of Milwaukee, Wisconsin, under the name "Rex FlexTop."



Designed primarily for tip-free conveying of bottles, jars, packages or small parts, the biggest advantage of FlexTop is its elimination of transfer points in the conveyor system. It does away with the danger of containers being chipped, tripped or otherwise damaged as they transfer from one chain or one conveyor to another. A FlexTop conveyor can be driven from one power source (within limits of chain loading), eliminating the need for transmission parts at transfer points, which is an added advantage. This can result in considerable savings both in first and operation costs. The speed at which the chain can be run is determined by the product being handled and by the length of the conveyor.

B.S.A. SIMPLIFIED SINGLE SPINDLE AUTOMATIC

B.S.A. Tools Limited, Birmingham, announce that they are now manufacturing a new Simplified type of single spindle automatic machine. The decision to undertake production of this additional type has been influenced by the present heavy demand for machine tools and the fact that there are many components which do not require a multiple operation machine and can be produced on a simple, less expensive machine.

Two sizes are at present available ; No. 48 Simplified shown in Fig. 1 has a bar capacity up to $\frac{1}{2}$ in. dia. and No. 68 Simplified is intended for a bar of $\frac{3}{4}$ in. dia. The basic construction of these Simplified machines is similar to that of the B.S.A. Single Spindle Automatic Screw Machines, but in many respects the design has been altered. Provision is made for one tool in addition to those on the cross slides, and the extended feed of bar stock permits the production of parts considerably longer than those usually accommodated on automatics.

Ample allowance is made for chips and their easy removal, and a compartment for storage of change gears is provided. Drive is by self-contained motor mounted at the rear of the base of the machine, Vee ropes being used to connect with the main gearbox shaft. All

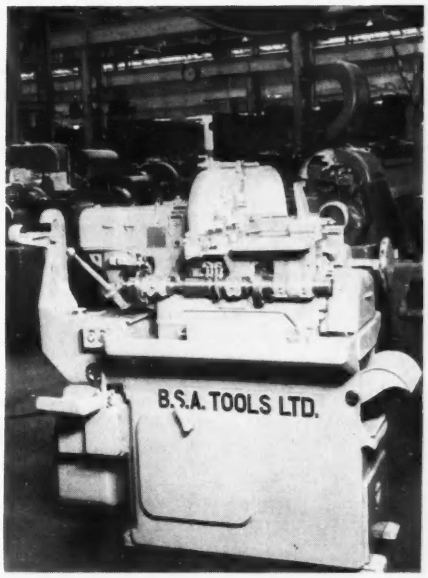


Fig. 1

gearbox shafts are carried on ball bearings and are lubricated automatically.

The plain workspindle is rigidly constructed to withstand maintained high speeds and heavy cuts and is mounted on roller bearings. Collets are toggle-operated and can be adjusted to suit stock diameter. The spindle drive is by a single sprocket which connects with a chain in the gearbox, correct chain tension being maintained by an adjustable jockey sprocket in the machine base. Adjustment on the No. 68 Simplified is made by the operator, but arrangements have been made for this to take place automatically on the No. 48 Simplified, since the smaller machine requires more frequent alteration in chain tension.

The front camshaft controls the cross slides, stock feed, work chute, collet opening and closing. It is driven by the lead camshaft from the backshaft, through a worm drive and pick-off gears which provide sixty-five different cycle times entirely independent of the spindle speeds. Change-overs from once cycle time to another are effected simply and rapidly by pick-off gears at the end of the machine.

The backshaft, seen in Fig. 2, is driven at a constant speed by a belt connected with the main drive shaft and can be engaged or disengaged by using a lever to operate a clutch. Dog clutches to control stock feeding, and collet opening or closing cams, are mounted on the backshaft, and are operated by adjustable trips positioned on the front camshaft.

The cross slides are totally enclosed at the front to prevent the entrance of swarf, and operation is by disc type cams mounted on the front camshaft. A third, or vertical slide can be fitted when required, the motion for this being taken from an additional cam on the front camshaft. Provision is made for the independent setting of each slide either forward or backward in relation to the centre line of the spindle.

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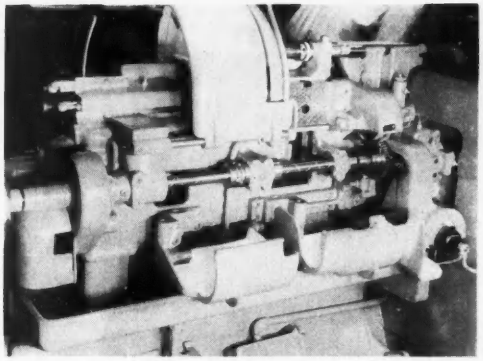


Fig. 2

In this simplified automatic, the conventional indexing turret is replaced by a plain slide carrying one tool holder which will accommodate any turret tool of standard type. When only two tools are necessary for the component, these will be accommodated on the cross slides, and the tailstock slide can then be used as a simple bar stop, or alternatively, if the components being produced are very long, a combined revolving steady and stop can be fitted. Provision has been made to deal with the production of components of various lengths, by enabling the tool holder to be adjusted forward or backward in relation to the slide, thus simplifying tool setting and considerably reducing the time delay.

Efficient guarding protects the operator from all moving parts and where necessary they are arranged to swing clear, so that parts such as the cross slides are easily accessible. Should the machine be subjected to undue strain, a slipping clutch in the cycle time gear train comes into operation and instantly stops all moving parts other than the spindle. Instantaneous stopping is similarly achieved when the remaining bar stock is insufficient to complete another component, the actuating device in this instance being incorporated in the bar feed mechanism. It will be appreciated that this feature is of considerable importance since it prevents tool damage, which may easily result from a short piece of stock being fed into the collet.

GENERAL PURPOSE FURNACES

Light-duty equipments are often pressed beyond their normal working capacities of output and temperature range to achieve a production schedule for which a full-scale production furnace would be too large and, therefore, an uneconomical proposition. Requirements in such circumstances call for an equipment which bridges the gap between light-duty furnaces and full-scale production plants.

In consequence, Wild-Barfield Electric Furnaces Ltd. have produced two horizontal models and a vertical model. The former models are the HW1 having a chamber 18 in. long × 9 in. wide × 5 in. high and the HW2 (see illustration) having the larger capacity of 31½ in. × 16 in. × 10 in. Their vertical model, known as VW1, gives a chamber size of 10 in. dia. × 20 in. deep.

The maximum operating temperature of 1050° C for these furnaces allows for a wide variety of heat-treatments, a few of which are listed below.

Hardening. In vertical types, single components of slender section and batches of work which can be suspended on jigs and quenched as a complete charge. In horizontal types, the hardening of carbon and low alloy steel tools and parts where components may be placed on the hearth direct, or small parts in large numbers may be placed in trays.

Preheating. As part of an installation for hardening high speed steel tools for preheating at temperatures in the range of 850/900° C.

Normalising and Annealing. For forgings and castings at all temperatures within the range.

Carburising. Small circular components such as gears and similar parts contained in cylindrical pots and boxes.

Powder Reductions. With the addition of suitable retorts, the vertical models can be used for the reduction of oxides in reducing atmospheres.

Vitreous Enamelling. For firing sheet metal and small castings in the horizontal models.

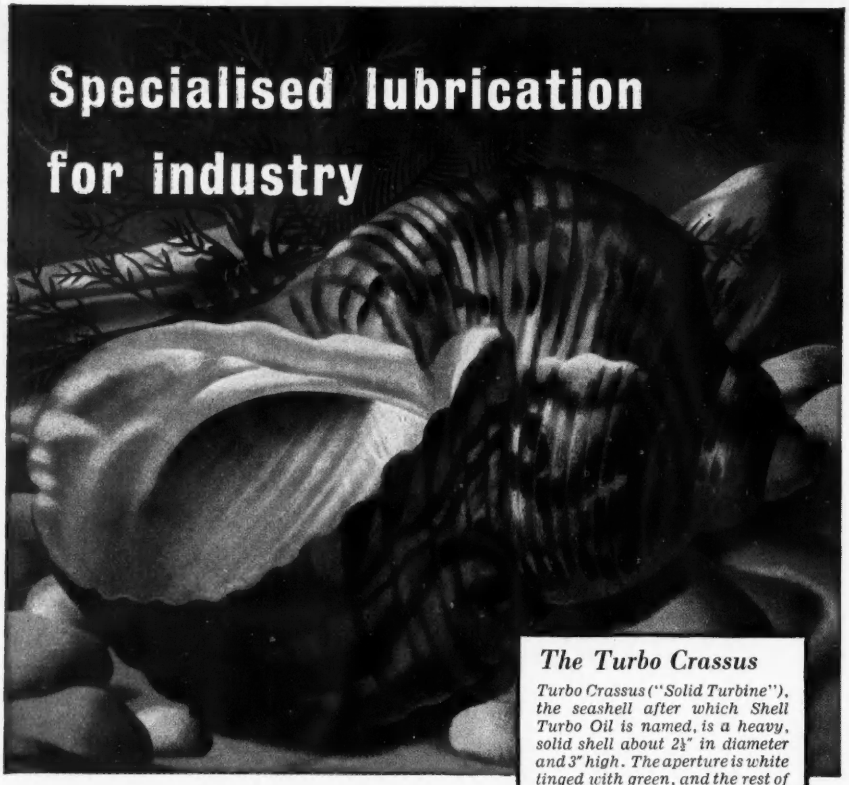
In view of the usage to which general purpose furnaces are subjected, control of temperature must be simple and safety devices incorporated. In the HW1 and VW1 models an energy regulator control panel has been found most satisfactory and, when used in conjunction with a pyrometer, will give accurate results. For the larger horizontal model HW2 an indicating automatic controller is generally supplied. The provision of a door switch ensures that when the door is opened the electricity supply to the elements is cut off and the operator is in no danger from shock when removing the charge. An excess temperature cut-out of the fusible type is incorporated in the control circuit.

These furnaces can be adapted to incorporate the injection of a controlled atmosphere into the chamber, the choice and method of plant depending upon the component to be treated and the most convenient supply available. In this respect the Paragen burner has many merits due to its compactness and the fact that the fuel required to provide the atmosphere is commercial paraffin.

SPECIALLY DESIGNED HEAT EXCHANGER

An excellent example of the range of high efficiency heat exchangers designed and manufactured by Petrocarbon Ltd., Manchester, is to be found in the cross counter current heat exchanger shown in the illustration overleaf, in the early stages of construction.

It was one of several such heat exchangers recently manufactured as part of a Petrocarbon low-pressure oxygen plant, now being built in Europe, designed to produce 200 m³ of pure oxygen per hour. This equipment is required to effect an exchange of heat between air and nitrogen, the air passing through the coiled tubes under a pressure of 75 psi and the nitrogen in the shell at a pressure close to atmospheric.



The Turbo Crassus

Turbo Crassus ("Solid Turbine"), the seashell after which Shell Turbo Oil is named, is a heavy, solid shell about 2½" in diameter and 3" high. The aperture is white tinged with green, and the rest of the shell is dirty white or greenish with angular black or brown patches. Found off North Australia and New Caledonia.

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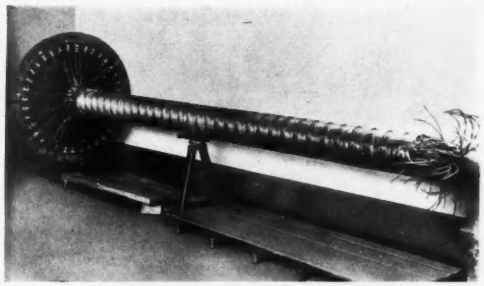

The heat exchanger contains a total wound length of 34,680 feet of $\frac{3}{8}$ in. o.d., solid drawn copper tubing in 289 separate, jointless tubes, each of which is 120 ft long. The whole of the winding was carried out on a $7\frac{1}{2}$ in. diameter core tube giving a total surface area available for the transfer of heat of some 3,400 sq. ft.

The individual tubes are expanded into the tube plates and then flooded with solder, and the shell, fabricated from copper sheet, is suitably jointed and mounted. External dimensions are: overall length 20 ft, diameter $22\frac{1}{2}$ inches.

LABORATORY CARRIER AMPLIFIER

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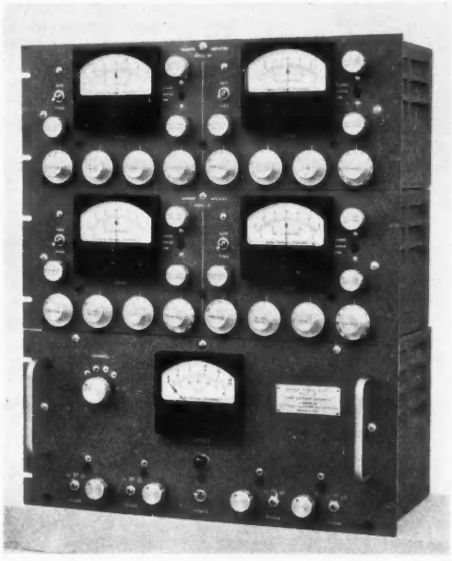

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HOW TO OVERCOME MATERIALS SHORTAGES IN PRODUCT DESIGN AND MANUFACTURE—(*Concluded from page* 297)

for scarce abrasion-resistant alloys and steels, for chutes, spouts, and liners handling such things as foods, liquids, coal, grain, concrete and cement. Other uses are for idler rollers, valves, guides for fabrics, pipes and fittings. To save cobalt, some porcelain enamels are made from a mixture of pure cobalt oxide and " concentrate " type cobalt-nickel ores.

POWDER METALLURGY PARTS : For a wide variety of mechanical parts, ranging from less than an inch to 5 or 6 in. diameter, iron and brass powders can be considered. Small housings, guides and pinions, gears, pistons, cams, sprocket wheels and ratchets are among the numerous applications. Sintered iron bands for shell rotating bands are giving good results in place of gilding metal. Forgings of stainless type 403 containing 13 per cent chromium are being conserved by using copper-infiltrated irons for jet compressor blades, and these latter materials have a high strength and ductility. Nickel-silver powder is used for making parts formerly machined from monel metal, for water pump rotors and pump liners.

Sub-micron iron powder, with magnetic properties between those of Alnico 4 and 5, has been developed in France for permanent magnets.

RUBBER-PLASTIC BLENDS : Corrosion-resistant hard materials composed of a blend of plastics and rubber, for instance, styrene copolymer resin and acrylonitrile rubber, have lately been introduced for pipes, tote boxes, gears, valve seats, seals, kick plates, and bathroom fixtures.

STEELS AND IRONS : Aluminium is being replaced by wrought and cast steel, cast iron and malleable iron. Automotive parts formerly made of aluminium, such as crankcases and pistons, are again being produced from cast iron. Unusual dimensional accuracy in grey cast iron thin-walled components is obtained with shell moulding techniques.

For many uses, nodular irons are replacing alloy steel castings and forgings, as, for instance, for large spiral bevel gears. Meehanite or quality-controlled cast iron is widely adopted, for instance, for joints in locomotive steam lines. Previously made of manganese bronze, and later of stainless steel, the meehanite casting satisfactorily withstands a steam pressure of 250 psi at 450° F. High-strength cast iron in place of bronze is being used for worm gears.

WOOD PRODUCTS : New uses of plywood include panels for railway coaches with a stressed-skin construction, baffle plates for television machines, instrument boards, jigs, fixtures, templates, trunks, etc. " Masonite " type wood-sheet hardboards are also a possible alternative for metals. Metal-wood composites, covered with aluminium, stainless steel or copper, are available in a wide range of compositions. Precision impregnated-wood bearings are used and have shown good life and anti-friction properties.

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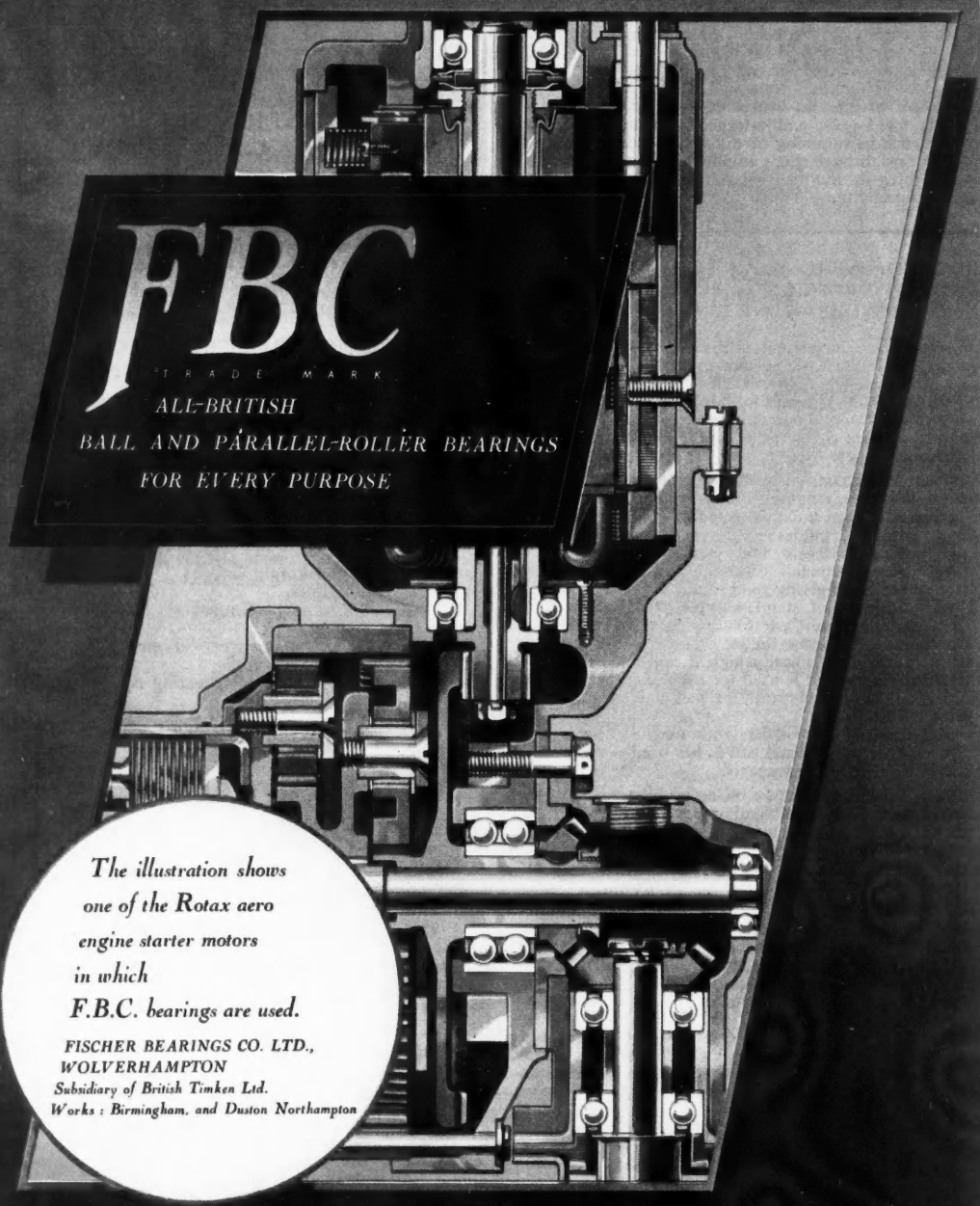
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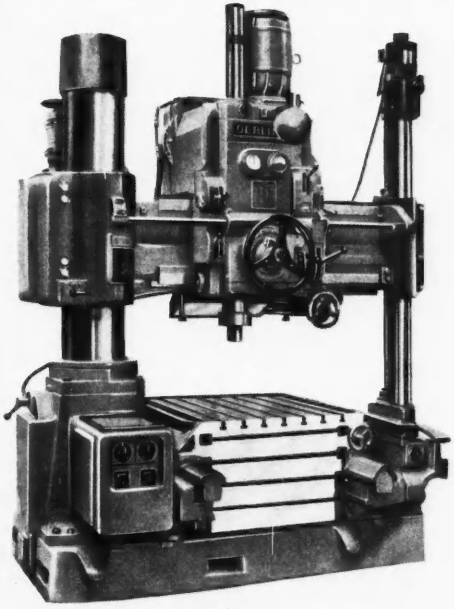
FIRST
EUROPEAN MACHINE TOOL EXHIBITION
PARIS, 1st—10th September, 1951

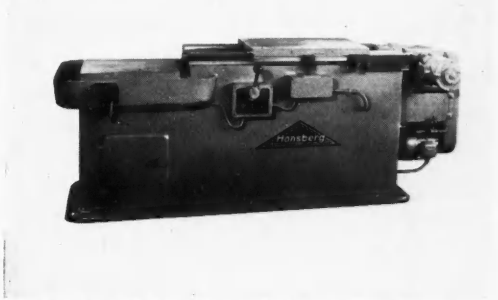
Technical progress by Machine Tool Makers in about 20 countries was noted throughout this Exhibition. Only a few representative designs are given here, but it is hoped that a few more machines can be described next month.

Fabrique de Machines-Outils Oerlikon Buehrle & Cie, Zürich-Oerlikon, showed their rigid radial drilling and boring machine type R2, which differs from normal radial drilling machines in that it has a supporting column on the outer end of the arm. This construction overcomes the lifting of the arm under load encountered on normal radial machines and so permits more accurate work to be performed. The machine also has a power-operated rapid table movement and special measuring equipment for co-ordinate setting of the table. Other distinctive features include: Automatic electro-magnetic clamping of the cross-arm on the two columns; the weight of the spindle, quill and tool is counterbalanced by adjustable springs housed in the spindle head; built-in table lighting system; and signal lights indicating rotation of the driving motor and operation of electro-magnetic clamps on columns and arm.



The drilling capacity in steel is 1¾ in., distance between columns is 60 in., and the maximum distance between spindle and table is 28 in. The machine has 18 spindle speeds ranging from 38 rpm to 1900 rpm and a total of 15 drilling and boring feeds.

Hahn & Kolb, Stuttgart, exhibited several "Honsberg" machine units, which are part of a range manufactured by this firm and are intended for building up into complete electro-mechanically controlled machines. The basic machine GM 400 incorporates the base, a traversing table and table feed unit, the latter providing both the machining feeds and the rapid traverse movement. The electro-mechanical movement control mechanism is placed on the front of the machine and operates by means of adjustable stops on the table and fixed electrical contacts on the base. A wide variety of movement combinations can be obtained to suit the machining requirements of individual components. These include machining feed in both directions against a fixed stop, feed with a dwell at the end of the feed stroke and rapid traverse movement in both directions. The machining units shown included a milling unit of 11 hp capacity, drilling units, the larger of which is capable of drilling holes up to 1 in. diameter in steel, and a deep hole drilling unit permitting automatic relieving. Interchangeable multi-spindle units can also be used on the machines.



The combination of automatically controlled movements, machining units and special work-holding fixtures can often replace several individual machining operations and increase production rates on a wide variety of components, such as crankcases, connecting rods, brake drums, etc.

L'Outillage R.B.V., Paris, manufacturers of small tools and machines tools, showed some of their broaching machines which constitute their main heavy products. The large vertical broaching machine can be used for both external and internal broaching. The external surface broaches are attached to the vertical pillar in the normal way, whereas for internal broaching there is a patented broach holder, which is bolted to the pillar and facilitates automatic quantity production. The machines can be operated manually, semi-automatically and automatically for all types of work. The power required for the broaching process is shown on a dial gauge and gives an instantaneous indication of any sudden or accidental power increase. The maximum permissible power can be pre-set and the machine stops automatically should this value be exceeded. All controls are grouped on the front of the machine and are within easy reach from the operator's platform. Push-button switches are provided for the electrical controls.

The machines are made in three sizes with maximum power of 13,000 lb, 22,000 lb and 33,000 lb. The corresponding lengths of stroke are 35 in., 47 in., and 51 in. respectively.

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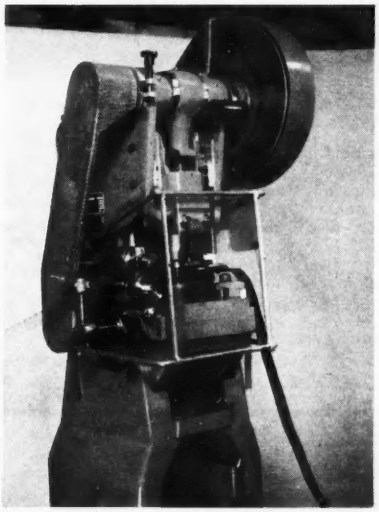
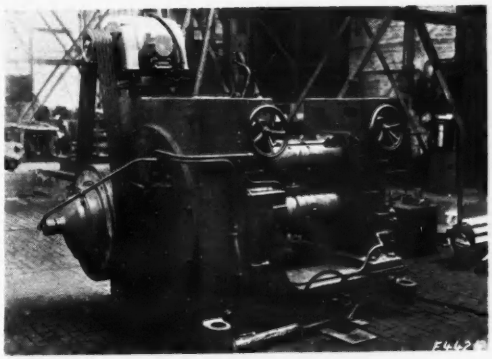
E. Beutler, Willisau, manufacturers of various types of mechanical medium-size and bench presses, displayed a new inclinable press of 10 tons capacity, which supplements their range of fixed upright machines. It has several interesting design features, including a very strong reinforced eccentric housing, ensuring maximum rigidity and accuracy. The table and body are one unit, a reliable and shock-absorbing clutch is used, and the machine is equipped with a number of safety devices. These include an anti-shock device which prevents the ram from over-running and gives complete positive control of the stroke in both directions. This is particularly useful in drawing, as it prevents incorrect sizing. The press can be provided with a gear drive for special purposes, such as drawing. In this case, the frame is further strengthened by two tie-bars.



The company also designs and manufactures a variety of automatic feed devices, such as roll-feeds, multiple roll-feeds and coil reels. Some of the machines are fitted with special "Agathon-Optimat" die-blocks, which have guide pillars provided with a large number of pre-loaded balls. It is claimed that this design permits highly accurate work even after prolonged use, the number of strokes per minute can be increased up to 2000 or even more, the life of the dies is increased, and lubrication is simplified as it only entails periodic application of bearing grease.

Eumuco A.G. für Maschinenbau, Leverkusen-Schlebusch, exhibited among other machines their new horizontal forging and upsetting machine. Its main feature is the tong-like gripping arrangement. The unusual design of the machine is claimed to have numerous advantages over the vertical types, including very simple and rapid adjustment of the upsetting punches, easy accessibility of dies which are exposed on three sides, rapid adjustment of die loads, and maximum rigidity and strength of the frame ensuring accurate work. The work material can be in the form of long bars or individual pieces cut to the required length, and existing tooling can be utilised. The machine is made in a number of sizes, with the upsetting power ranging from 50 tons to 3150 tons, with die openings of $2\frac{1}{2}$ in. to 11 in. respectively. The number of strokes per minute is 85 on the smallest machine and 15 on the largest type, the power behind being supplied by motors of 5 hp and 120 hp capacity.

Another very interesting machine manufactured by the same company is the roll forging machine, which can be used for finish rolling and for flattening of die



forgings. The machine has a pair of rolls mounted on heavy bearings, supported in a rigid frame. The forging dies are composed of individual annular segments attached to the rolls. These segments normally cover half the roll periphery, and adjacent segments are used successively to obtain the desired shape. The rolls perform one revolution only and the whole operation is very rapid, so that after having passed through a number of die segments, the work is still hot enough for finish forging without re-heating. For shorter work, the segments only cover a quarter of the roll periphery and the rolls only perform half a revolution, with a consequent speeding-up of the process. The output of the machine exceeds that of a swaging hammer by 200 to 300 per cent, and due to the uniformity of the finished forging, the weight of the blank can be appreciably reduced. The smallest size, RW00, has $11\frac{13}{16}$ in. wide rolls, $14\frac{9}{16}$ in. maximum rolling length and the rolls rotate at 140 rpm. Corresponding values for the largest size, RW3, are $29\frac{13}{16}$ in., $48\frac{13}{16}$ in. and 30 rpm respectively.

Tarex Ltd., Geneva, showed a new single spindle automatic turret lathe, Model TAR 64. It is designed for both bar and chuck work, without changing the spindle, so that the change-over from bar to chuck work is very simple and quick. The maximum machining capacity for the former is $2\frac{1}{2}$ in. and for the latter 7 in. The maximum machining length is $4\frac{3}{4}$ in. for both methods of operation.

The front, back, and vertical slides are actuated by widely adaptable standard cams of the flat type. These are easily fitted and removed and can be produced very accurately and cheaply, so reducing tooling costs. The turret has six tool positions and a maximum travel of $4\frac{3}{4}$ in. The work spindle is mounted on roller bearings, the front bearing being an adjustable double-row roller bearing. The spindle speed range is very extensive in both the forward and reverse directions.

The non-cutting times are reduced to the minimum by the rapid traverse movement of the turret. This also makes it possible to carry out the machining of various components with the same turret cam and yet maintain cycle times at an economic level, by accelerating idle operations.

Max Müller-Maschinenfabrik Brinker, Hanover, exhibited the "Eltromatic" lathe. It has an interesting feature in the electronic spindle speed control device, which automatically maintains a constant cutting speed over a range of diameters up to a ratio of largest diameter to smallest diameter of 7 : 1 to 8 : 1. This control is actuated by a potentiometer built into the cross-slide. On suitable components the advantages claimed over normal lathes include considerably lower machining times with a consequent increase in chip removal in a given time, simple pre-selection of cutting speed, uniform surface finish on stepped diameters and faces and increased tool life. If required, the normal

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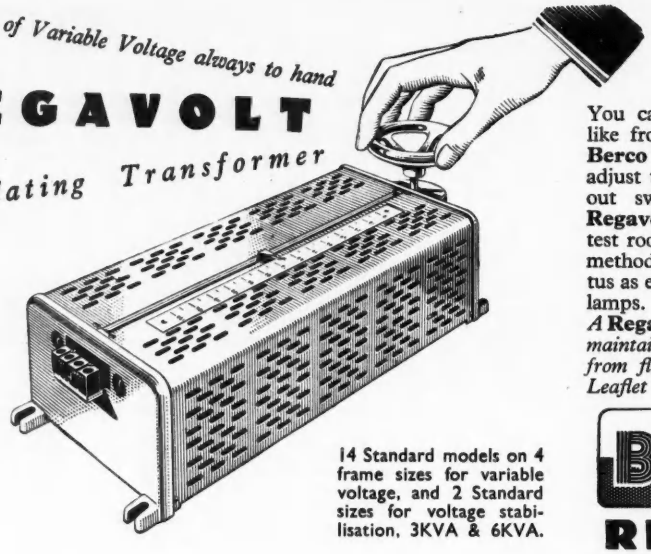

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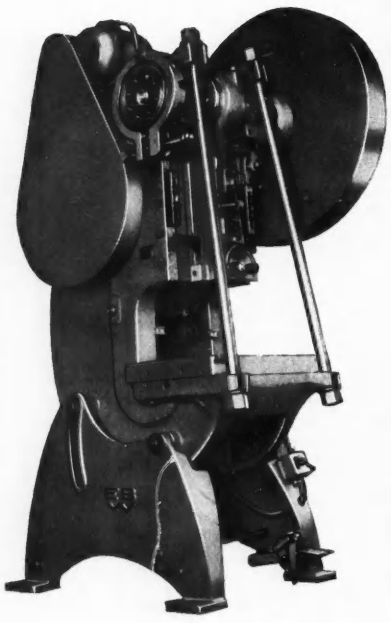

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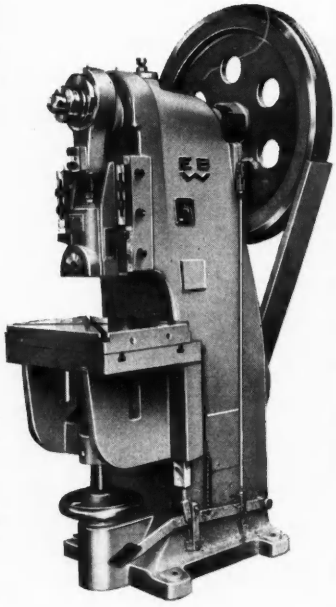
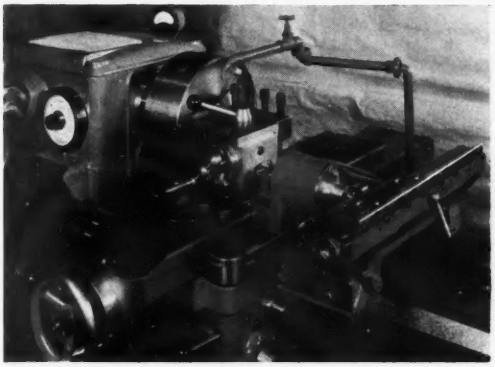
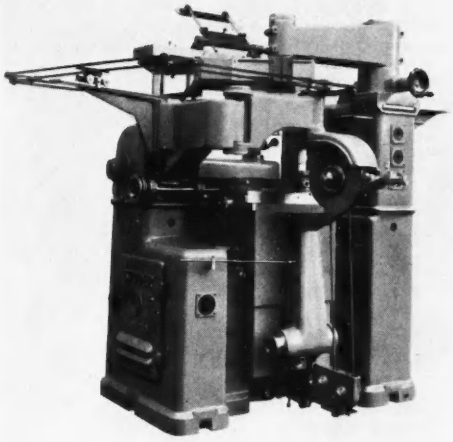




method of speed selection can also be used. The speeds are then steplessly variable and can be altered while the machine is operating. The machine is produced in two sizes, the centre heights being 11 $\frac{13}{16}$ in. and 13 $\frac{13}{16}$ in. The distance between centres varies from 30 in. up to 100 in.

Fritz Studer Ltd., Glockenthal-Thun, exhibited their new profile grinding machine, type PSM 250. The machine is similar to the existing smaller type PSM 130. The profiles are ground directly from the template, and typical applications include the grinding of profile gauges, grinding of flat and circular form tools with clearance angles, and relief grinding of dies and punches. A circular grinding attachment can be used in place of the indexing table to allow circular form grinding up to 10 in. diameter and 16 in. length. A new device for the automatic lead of the stylus bar is fitted to the template table and is driven from the circular grinding attachment spindle. It provides a uniform, adjustable travel, so improving the quality of the profile ground surface, making it independent of the machine operator's skill. The stylus bar can be advanced in both directions and its travel can be limited by two adjustable stops. The device can be taken out of operation by loosening two



screws, when the stylus bar can be guided in the normal way by hand. The pantograph is adjustable from a ratio of 1:1 to 1:10. A maximum length of 16 in. can be ground at one setting, and templates up to 24 in. long can

GASEOUS NITRIDING

(*Concluded from page 292*)

suitable for applications where a rubbing action between two metal surfaces occurs, such as gears, camshafts, cylinder liners, pins and bushes.

Retention of hardness at elevated temperatures. The hardness of a nitrided case is retained on reheating to temperatures up to the nitriding temperature for long periods. Even when held for short periods at 650° C, the hardness is not reduced to a very great extent. This is clearly shown in Fig. 5, which also shows the effect of heat on a carburised case for comparison.

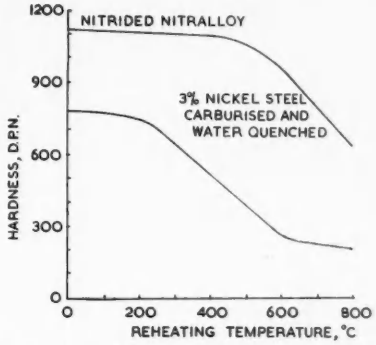


Fig. 5. **Graph showing the effect of heating nitrided Nitralloy and carburised 3 per cent nickel steel.**

Hardening parts of intricate design. Because there is no quenching required after nitriding, parts of intricate design, such as plastic moulding dies, may be hardened without fear of cracks or distortion caused by quenching.

Resistance to corrosion. It has been shown[5] that nitrided articles resist corrosion by the atmosphere, alkalies, crude oil, natural gas combustion products, tap water, superheated steam and still salt water. However, aerated salt water and alternate wetting with salt water and drying cause a pitting type of attack. The nitrided case does not resist the mineral acids such as hydrochloric and sulphuric acid.

TABLE IV.

Condition of Sample	Endurance Limit
Unnitrided without notch	20
Nitrides without notch	40
Unnitrided with half-circle notch ..	11
Nitrided with half-circle notch ..	39
Unnitrided with V-notch	11
Nitrided with V-notch	36

Resistance to fatigue. Nitriding increases the endurance limit, as determined by reversed bending. Fatigue failures begin at the junction of the case and the core, indicating that the characteristics of the core control the endurance of the nitrided part. Because of this, surface features leading to stress concentration have a much smaller effect on nitrided specimens than on other material. Table IV shows some comparative results of fatigue tests.[2] The increased fatigue resistance of a nitrided part makes it very suitable for spindles, crankshafts and other rotating engine components.

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(1) M. S. FISHER and Z. SHAW: The Mechanism of Nitride Hardening. *J. Iron and Steel Inst.*, 1937, 136, 143.
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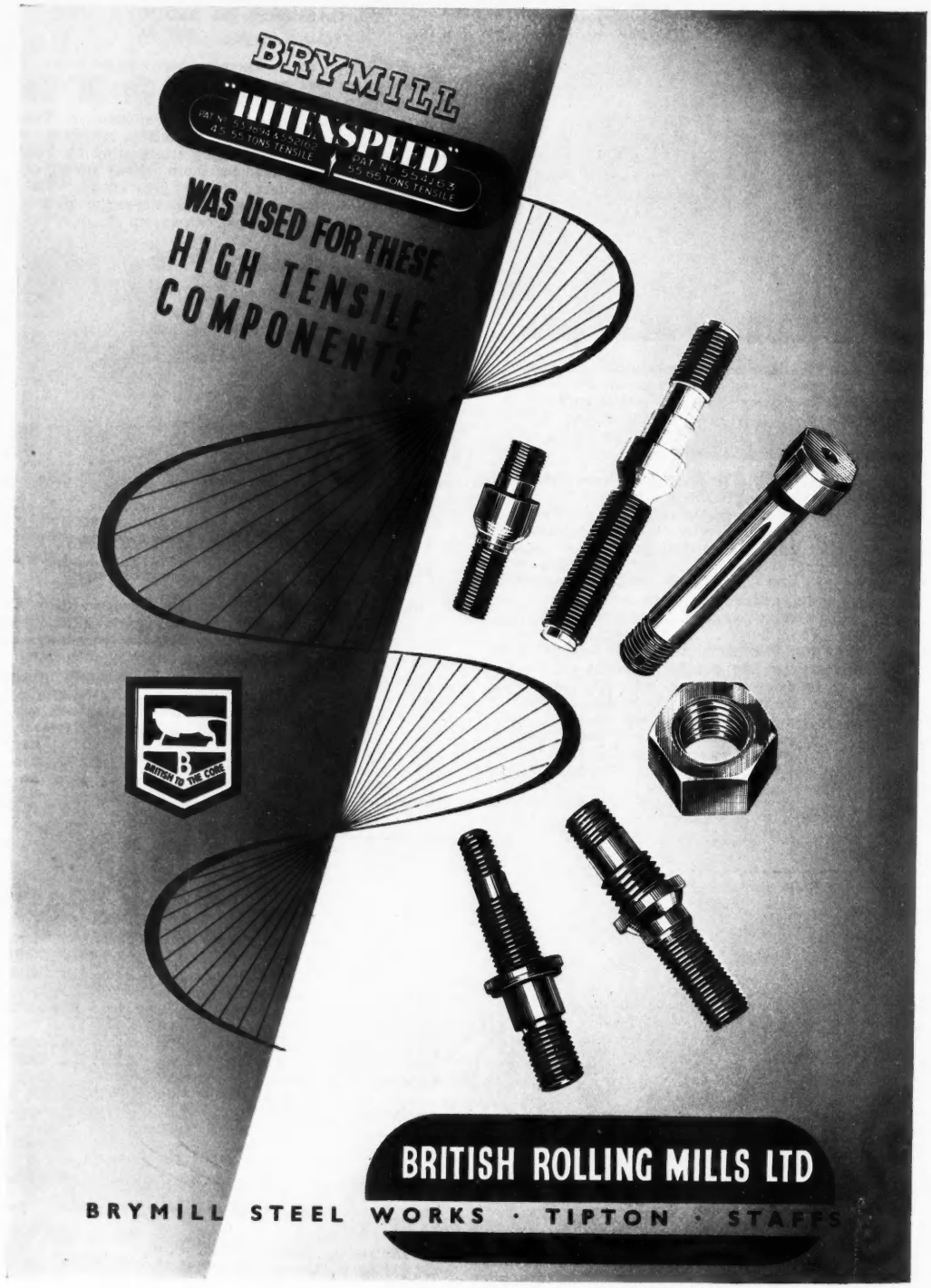
(3) H. W. MCQUAID: Working Rules for Nitrogen Hardening, *The Iron Age*, May 1929, 17, 641.
(4) C. F. FLOE: The Nitriding of Steel, *Metal Progress*, December, 1946, 50, 1212.
(5) R. SERGESON and H. J. DEAL: Further Investigations in Nitriding, *Trans. A.S.S.T.*, 1930, 474.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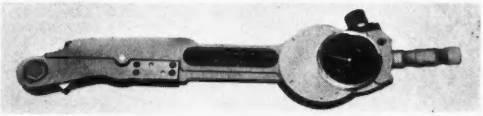
be accommodated on the template table. The maximum thickness of flat work is 4⅜ in. The grinding wheel head is mounted on a double-arm bracket and is free to swivel in accordance with the movement of the stylus bar. Grinding wheels of nearly 10 in. diameter and ½ in. width are used.

Eduard Wille, Wuppertal-Cronenberg, manufacturers of spanners and hand tools, exhibited a torque wrench with an automatic load release device. It incorporates an indicating dial giving instantaneous readings of the applied load. After initial setting of the release load, the dial can be removed for rough or repetition work and can be replaced by a plain disc. The tool is compact and is operated by one hand only.



It can therefore be used for repeated tightening of bolts, etc., on production, even where the available space is confined. An extension handle is provided for reducing the force required for applying large torques. The scale of the indicating dial can be calibrated in ft-lb, and six sizes, with maximum torques ranging from 11·5 ft-lb to 360 ft-lb, are available.

Aktiengesellschaft Vulkan, Köln-Ehrenfeld, exhibited a very versatile universal grinding machine, model US 5. It can be used for external cylindrical grinding, internal grinding and taper grinding, as well as for surface grinding of areas up to 19 in. × 7 in. Cylindrical and surface grinding can be carried out at one setting of the component, with considerable gain in accuracy and speed of operation. The machine is hydraulically operated and has steplessly variable table traverse, spindle feed and work spindle speed. All the controls are conveniently grouped on the front of the machine, each of the six electric motors used on the machine having a separate push-button and pilot light. The maximum diameter of work for plain cylindrical grinding is 6 in., maximum internal diameter 4 in., and maximum length of work 20 in. The versatility of this machine makes it well suited for tool-room work, and the makers claim that it is equally suitable as a special machine for quantity cylindrical, internal and surface grinding work.

CENTRELESS BAR TURNERS AND BILLET PEELERS

(*Concluded from page* 304)

hydraulically or pneumatically, the feed and output carriages being cable-driven and push-button controlled. Each cutter head can carry up to 10 knives. The delivery of finished bars and the gripping of new stock takes place automatically.

(d) Designed as a heavy-duty machine, the input and output carriages are operated by means of a lead-screw running along the whole length of the machine. Separate drives are provided for feed driving the feed screw and the cutter head.

(e) This is a machine for the production of accurate diameters, employing two consecutive thread-cutting heads and a finishing head. The first thread cutter aligns the bar and, through the cutting action, also feeds it forward. The second thread-cutter removes the crests of the thread previously cut, the finishing tool then producing the final dimensions. Such a procedure, however, lends itself only to light cuts.

(f) This shows the latest development in high-output peeling machinery, largely automatic in operation and suitable for the employment of carbide tools. Its special feature is the "torque-chipper"—a set of cutters placed before the peeling head, which cut longitudinal grooves into the bar, thereby ensuring that the chips produced in peeling are of short length.

Billet-Peeling Machines

These heavy-duty machines, with drives up to 300 hp and capacities up to 350 mm (14 in.), usually have one cutter head only. The feed is usually hydraulic or occasionally pneumatic, and incorporates a quick-return mechanism for the input-carriage.

Cooling and Lubrication

Drilling oil with a high fat content, in about 1 : 10 dilution, is used as coolant under high pressure. A continuous check on the density of coolant may be carried out according to the author's method:—Drops of the coolant are placed on a roughened cast-iron surface. If, after 24 hours, the dried drops leave corrosion marks, this indicates that the oil has been reduced in fat content. Alternatively, a viscosity test may be employed.

Subsequent Operations

For the securing of closer tolerances and improvement of surface quality, centreless grinding or a straightening, sizing and polishing machine is employed. Straightening alone is often sufficient. It may be noted that peeled and subsequently straightened and polished bars may be distinguished from drawn bars by placing them in a pickling bath, where, after a short time, the tool marks become visible.

Uniformity and high output can only be secured through constant control over conditions, and therefore the tendency is towards ever greater automatisation of peeling machinery. Modern control apparatus (e.g., light-signals indicating deviation from correct diameter or surface smoothness) will find wide scope for application in this field.

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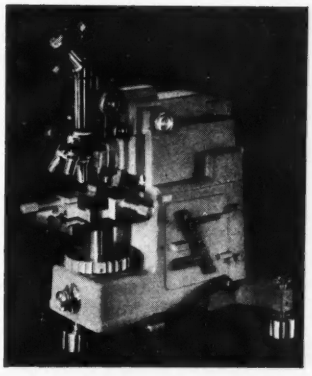

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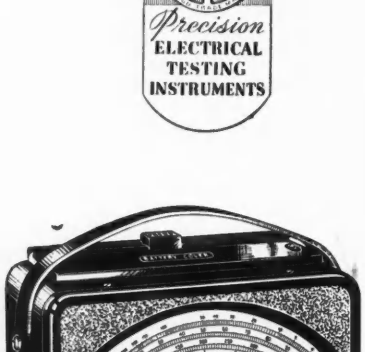

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NEWS OF THE MONTH

PERSONAL

Mr. E. W. Ashby, B.Sc. (Eng.), sales engineer attached to the Liverpool Branch Office of British Insulated Callender's Cables Ltd., has been elected chairman of the Mersey and North Wales Centre of the Institution of Electrical Engineers.

Dr. C. Dannatt, O.B.E., M.C., M.I.E.E., director and chief electrical engineer of Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester 17, has been appointed director of research and education in succession to **Sir Arthur P. M. Fleming, C.B.E., D.Eng.,** who will retain his seat on the Board. **Dr. Dannatt** has also been appointed assistant managing director. **Mr. H. West, M.I.E.E., M.I.Mech.E.,** assistant chief electrical engineer, has been appointed chief electrical engineer, in succession to Dr. Dannatt, and has also been appointed to the Board of the company.

The announcement that **Sir Arthur P. M. Fleming,** while retaining his seat on the Board of the Metropolitan-Vickers Electrical Company Ltd., has relinquished his executive duties as Director of Research and Education in that Company, should not be taken to imply even partial retirement. He is in fact undertaking wider responsibilities, having been appointed Director of Research and Education, A.E.I. Ltd.

Sir Arthur has for some years been Chairman of the A.E.I. Research Committee, which co-ordinates the research activities of the manufacturing companies within the Associated Electrical Industries Group, and the long-term research of the A.E.I. laboratories at Aldermaston, Berks. In his new capacity he will undertake also the co-ordination of the educational work of the various companies.

Mr. A. H. W. Dawson has been appointed resident manager of the South Dock Works of the North Eastern Marine Engineering Co. (1938) Ltd.

Mr. R. M. Dennis, executive director of A.B.C. Motors Ltd., Walton-on-Thames, has been appointed managing director of the Company, the whole share capital of which has been acquired by Vickers Ltd.

Mr. C. L. G. Fairfield, M.A., A.M.I.F.E., A.M.I.Mech.E., has been appointed manager of the valve division of Mullard Ltd., Century House, Shaftesbury Avenue, London, W.C.2.

Squadron Leader D. R. Kinnell, M.I.P.E., M.I.B.F., Assoc.I.Mech.E., has been appointed personal assistant to the general manager of Pratchitt Brothers Ltd., Denton Iron Works, Carlisle.

Sir Felix Pole has been elected chairman of The Pulsometer Engineering Co. Ltd., Nine Elms Iron Works, Reading, in succession to **Mr. Eliot Hodgkin. Mr. R. G. W. Bliss** and **Mr. A. V. Price** have been elected directors, and **Mr. J. Elliott** has been appointed secretary of the Company.

Colonel John Reading, M.B.E., B.Sc. (Eng.), M.I.E.E., has been appointed assistant Engineer-in-Chief of the Post Office.

Mr. H. C. Reeves, B.Sc.(Eng.), A.M.Inst.C.E., D.I.C., has been appointed chief fan designer of Air Control Installations Ltd., Ruislip, Middlesex.

Mr. Philip A. Singleton, B.Sc. (Eng.), Assistant to the Chairman and Managing Director of Monsanto Chemicals Ltd., 8 Waterloo Place, London, S.W.1, has been elected to the Board of the Company.

Mr. Ernest F. Souchotte has been appointed manager of the Finnieston diesel engine works, Glasgow, of Harland & Wolff Ltd. **Mr. Frederick H. Duncan** has been appointed manager of the Scotstoun works, Glasgow.

Mr. H. Streets, chief technical engineer of Richard Sutcliffe Ltd., Horbury, Wakefield, has been appointed technical director of the company.

Mr. H. Trencham, M.Inst.C.E., M.I.E.E., consulting switchgear engineer of The British Thomson-Houston Co. Ltd., Willesden, has retired after nearly 36 years service with the company.

Miss E. P. Wood and **Mr. J. A. J. Blanckensee,** joint general managers of the raw materials division of George Cohen Sons & Co. Ltd., have been elected to the Boards of Pollock Brown & Co. Ltd., Westbourne Park Coal & Iron Co. Ltd., and Southall & Hayes Coal & Iron Co. Ltd.

BUSINESS NOTES

Experimental Types of Crystal Devices without catswhiskers are now being made by BTH, and, from their power handling characteristics, should be capable of operating, not only small radio sets, but public address systems, cinema amplifiers, power rectifiers, etc.

These new germanium devices have simple wire connections soldered onto the surface of the germanium, and crystal triodes can be made to generate oscillations, like a valve, with battery power of less than one microwatt.

At the other end of the range is a water-cooled power rectifier that will handle about 100 amperes in an area of one square centimetre.

A Revised Compressed Air System. An interesting development of the compressed air equipment for starting medium sized diesel engines, has recently been put into production by the Hymatic Engineering Co. Ltd., Redditch, and will be fitted to a series of engines manufactured by H. Widdop & Co. Ltd., Keighley. The development is based on the use of a relay operated injector valve and a small distributor which gives a simplified piping run for the main air starting line and reduces the amount of compressed air used per operation. Due to the simplicity of the large diameter piping run there is a considerable saving in the cost of this pipe and in the cost of its manipulation, the small diameter relay pipes are easily shaped and can be neatly conduited between the distributor and various injector valves.

The injector valve consists of an air relay operated by a pulse of air from the distributor, the air relay in the valve connects the main trunk line to the cylinder so providing the turning force. At an appropriate point on the piston stroke the air is cut off by the distributor to the relay which closes the injector valves. The compressed air in the engine cylinder is then exhausted in the normal way. The distributor supplies relay air control to the injector valves to give a smooth and continuous starting effort until the engine fires when the compressed air supply is turned off.

Other items of equipment in the system consist of the usual air compressor and storage bottle and a master stop cock.

An International Industrial Research Institute to serve the European economy will be established in Europe this autumn. To be known as Battelle International Institute, the European activity is being established by Battelle Institute, Columbus, Ohio, the world's largest industrial research foundation. According to Director Clyde Williams, it proposes to serve European industry, on a non-profit basis.

Battelle International will establish research investigations in existing research institutes of Europe and in European universities and technical schools. It will also operate its own laboratories on the continent, the exact locations of which will depend upon the outcome of negotiations now in progress.

Financial support for these activities will be derived from industrial sponsorship, from endowment, and from income from patents owned by Battelle. It will conduct research in the fields of applied chemistry and physics, metallurgy, fuels, ceramics, electronics, theoretical and applied mechanics, the engineering sciences, and agriculture.

John S. Crout, for many years Assistant Director of Battelle, has been named Executive Director of the new institute.

DATA SHEETS

for Engineering Students & Apprentices

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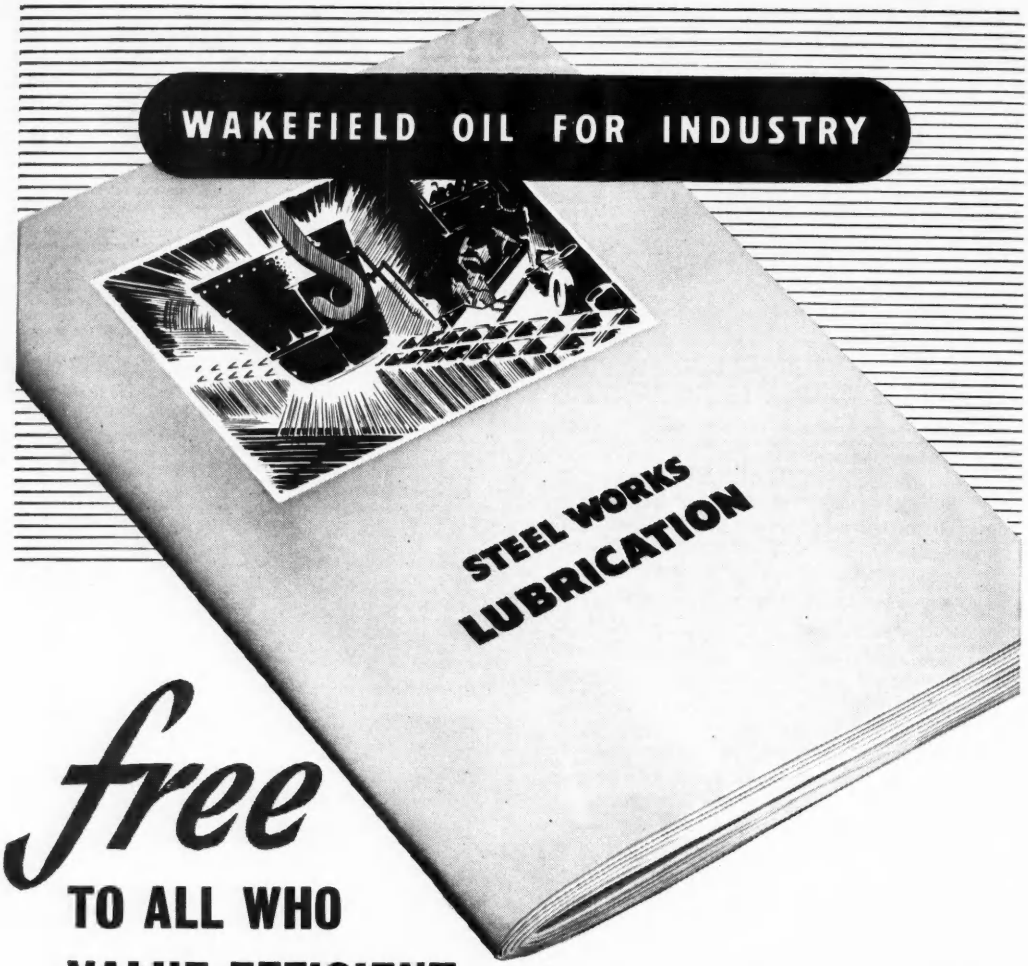

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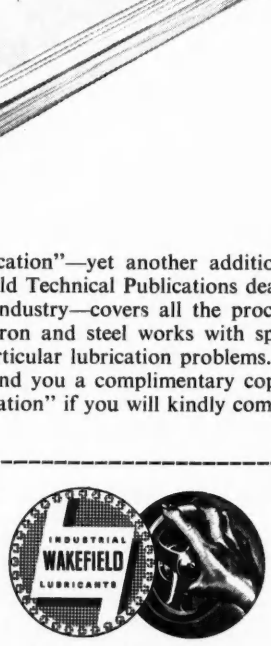

APPROVAL OF ELECTRICAL EQUIPMENT FOR CANADA

The conditions under which electrical equipment is used in Canada are different from those obtaining in the United Kingdom. For industrial equipment a three-phase supply at 550/600V with full line voltage to earth is used in some Provinces, particularly in Eastern Canada, whereas in the U.K. the supply does not normally exceed 440V with 250V to earth; for this reason equipment designed for use in the U.K. may not necessarily be suitable for Canadian conditions, particularly in regard to electrical clearances to earth and between phases.

The procedure in Canada in connection with approval of a piece of electrical equipment is to identify it by means of descriptions sometimes accompanied by illustrations of the important parts; full compliance with the Canadian Electrical Code is assured by carrying out the tests specified, normally at the C.S.A. Laboratories in Toronto. Similar procedure has now been adopted in the U.K., except that the tests are carried out either in the manufacturers' works or by an independent test house. Important tests in works are always observed by a B.S.I. engineer specially conversant with C.S.A. practice, but for other tests and in appropriate cases, test certificates are accepted from the manufacturers, these certificates being countersigned by a responsible member of the firm with the approval of the B.S.I. engineer during his visit to the works.

A report on the equipment concerned is compiled (including identifying descriptions and the results of tests) and this report is sent to the C.S.A. Laboratories in Toronto. After confirmation by them, the report is recommended to the C.S.A. Approvals Council. Thereafter the applicant is informed, through the B.S.I. that provisionally he may use an Approval Number.

There are, at present, some 80 individual Canadian approvals specifications to cover all types of equipment. Where the apparatus cannot be covered by an individual specification it is necessary to apply the relevant parts of other specifications, and the knowledge of which to apply can be obtained only by experience; furthermore, there must necessarily be a delay between the introduction of new types of equipment and the preparation of an approval specification to cover them, and it has therefore been necessary in certain cases to check with the C.S.A. Laboratories in Toronto regarding details of any unpublished special requirements introduced to supplement the specifications. In this way a large amount of information is being collected in the U.K. and as this grows it will obviously be necessary to refer to Canada less frequently.

Approvals have been received for cable, domestic accessories and applicances, industrial switch and control gear, machine tools, motors, welding equipment, food-preparing machines, office machinery, fans, and other allied equipment.

The B.S.I. has prepared a complete classified list of U.K. equipment which has received C.S.A. approval to date. Those interested may obtain details on application to the B.S.I./C.S.A. Approvals Division at 24/30 Gillingham Street, London, S.W.1.

WELDING IN AMERICA

The Specialist Team on Welding visited the U.S.A. in October and November last year under the auspices of the Anglo-American Council on Productivity and the technical assistance programme of ECA, and has now produced its report containing over 60,000 words and some 50 diagrams and illustrations. The Team contained eighteen representatives of British industry drawn from the following fields :—

Welding plant, materials and equipment
Railways, locomotives and rolling stock
Constructional steelwork
Pressure vessel manufacturers
Shipbuilding
Sheet metal work
Electricity supply
Inspection
Research
Trades Unions

The major headings of the Report are :—Mechanical handling; Material for welding, its preparation and heat treatment; Welding processes and equipment; Inspection and testing; Working Conditions; The cost of welding; Welding in particular industries.

"The Team has formed the opinion that American productivity in welding is higher than British productivity. The difference may not be very great, but this should not detract in any way from the urgency of applying at home those features of the American welding industry which, if applied here, would certainly improve our productivity."

Among those factors affecting productivity, precedence is given to matters concerning personnel and working conditions. It is emphatically stated that "the American working man has more clearly in mind the direct relationship between greater productivity and a higher standard of living" than has his British opposite number, and the reasons given for this are :—

(1) That foodstuffs and other goods are available in the shops for any money that is earned.
(2) That in order to maintain the high standard of living to which the American has become accustomed, it is essential that he should retain his job.
(3) That the unity of interest of the workers, the trades unions and the individual employers is encouraged by the system of 'local' unions." (p. 73).

Among the technical factors affecting productivity, perhaps of great importance is the attention given to planning and routing of work and materials, and the use of all possible mechanical aids and automatic devices to reduce to an absolute minimum the manpower required. This affects the actual welding operation, and is shown by the much greater use made of automatic welders and

LATEST INDUSTRIAL LITERATURE

1. The Lubrication of Steam Turbines. Edited with great care, this 130-page book should prove to be of utmost value to all engineers interested in the complex problems and the present-day technique of steam turbine lubrication. The book contains 34 excellent illustrations.

2. Machine Tools on Production. Well designed and profoundly illustrated 32-page catalogue depicting an extensive range of drilling and milling machines. In addition to brief details and specifications, full-page photographs, including four natural colour photographs, show the machines on production in customers' works. Both design and production of the brochure represent very high standard.

3. Cleaning Machinery at Half the Cost of Rags. 16-page illustrated brochure offering a trouble free service of loan of stock, cleaning, replacements, collection and delivery at a low cost.

4. Insulated Winding Wires. Folder containing Technical Data Sheets with specifications of a range of winding wires which include enamelled wires, silk, rayon, cotton and glass fibre covered wires, enamel and paper covered wires, Litz wires and textile covered bunched wires. A pocket of the useful folder contains small brochures with information regarding the technical properties together with tables of sizes, dimensions and reeling data.

5. Prevention of Screw Thread Seizure. Illustrated information sheet dealing with dispersions for the treatment of all sizes of screw threads. Applications include the treatment of the threaded couplings of light alloy pipe systems in aircraft; large steam turbine casing bolts; screw threads on gas turbine jet engines; studs and bolts on the superheater headers of boilers, and high pressure steam pipe flanges. Practical tests have shown that these coatings on screw threads will withstand temperatures of 700-800 C. for some considerable time thus preventing seizure.

6. Self-lubricating Porous Bronze Bushings and Bearings. Illustrated leaflet describing the advantages and potentialities of these bushings and bearings as alternatives to solid bronze bushings and bearings. A variety of questions put to the manufacturers by engineers, designers and prospective users have been answered in the leaflet. Questions concerning loads and speeds, tolerances, shaft clearances, range, fittings, prices, etc., are answered in a concise manner. Specifications for both standard and non-standard cylindrical bearings, flanged and spherical bearings and washers and thrust rings are included.

7. Ingots. 28-page brochure with specifications of a wide range of ingot metals. Includes many of the most recent specifications, also specifications of some recently introduced metals which have been developed to conserve tin and to permit the maximum efficient utilization of secondary materials. The range covers admiralty gunmetal, gunmetals, phosphur bronze, brasses, brazing metals, aluminium bronzes, manganese bronzes, bearing metals and bronzes.

8. Tool Steels. Well produced 66-page catalogue with some excellent illustrations. Contains in easy, accessible and brief form, much valuable information on the application, manipulation and heat treatment of high grade tool steels.

9. British-made Super-Centrifuges. The use of super-centrifuges has proved to be advantageous in an increasing number of industrial applications which include engineering works of all kind, public utility undertakings, food, chemical and pharmaceutical manufacture, steel mills, marine service, etc. The illustrated 12-page brochure offered, contains numerous photographic illustrations and a coloured sectional view to show the application of centrifugal force to a mixture of two immiscible liquids containing suspended solids heavier than either liquid and the various types of super centrifuges with descriptions concerning their applications.

10. Pneumatic Control Equipment. Profoundly illustrated 46-page brochure contains much valuable information on pneumatic cylinders and valve gear used on all types of machinery. 50 to 100 per cent production increase per machine, often accompanied by a reduction in the amount of labour required, are some of the remarkable effects resulting from the introduction of pneumatic control system. The brochure contains specification and detailed illustrated description of the various types of valves, cylinders, fittings and accessories available. Some typical applications are also described and illustrated.

11. Industrial Conveying. Folder containing five nicely illustrated brochures which should prove to be of interest to those interested in the mechanisation of industry. Technical details, illustrations and general information contained in the brochures, relate to conveying equipment in Chemical and Processing Industries; General Mechanical Handling; Coal, Coke and Ore Handling; Industrial Conveyors; and Mechanical Handling in Quarries and Sand and Gravel Pits.

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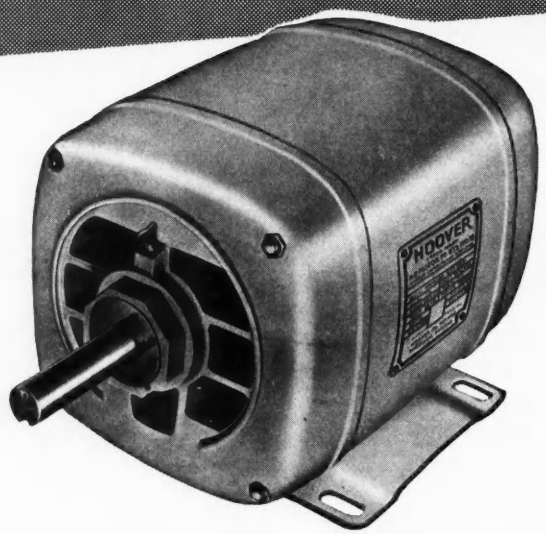

IT IS not yet two years since the latest Hoover 'fractional' first made its appearance. But the men who built it drew on thirty years of electrical engineering experience. They listened to industrialists and found out what they wanted . . . they listed snags in existing motor design and found ways to eliminate them . . . and they added many new ideas of their own. That is why the Hoover 'fractional' so quickly found its place — at the top.

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manipulators and the provision of local lifting gear so that the welder does not have to wait until the shop crane is free to move or turn his job.

Nothing completely new was found in the technical field, but the Team was impressed with the possibilities of a welding gun which is continuously fed with a bare wire electrode from a coil, and in which the electrode and arc are shielded with an inert gas. Neither the hand nor automatic version of this gun is yet available in this country, though an experimental model has been in use for about two years.

The Report states that the low-hydrogen electrode is increasing in popularity, and that there is a tendency with all electrodes to use somewhat smaller sizes than previously—$^3/_{16}$ inch diameter is the commonest size of electrode ; $\frac{1}{4}$ inch diameter is very popular, but $\frac{5}{16}$ inch diameter is hardly ever used. Pre-heating and post-heating of pipes is not infrequently done by means of induction heating using the normal 60-cycle supply.

With respect to plant, the A.C. single-operator set is increasing in popularity, but the multi-operator set with separate reactors, so commonly used in Britain, is virtually unknown in the U.S.A. Automatic welders, both submerged arc and covered electrode type, are much more common than here. The manual submerged arc machine, introduced within the last few years, is not very popular, owing chiefly to the welder's difficulty in following the line of the weld. A number were, however, seen in use as semi-automatic welders.

In resistance welding, the most significant features were the increasing use which is being made of three-phase machines and of multi-head automatic spot welding machines. Several examples of flash welding were seen in which virtually no preparation was used on the mating parts. This is entirely different from British practice, but appeared to be satisfactory—and naturally cheaper. Some remarkable examples of the adaptability of the resistance welding process were seen, as for example in the flash welding of the longitudinal seams of 40-foot pipes, the mash-welding of floor grids and the roller spot welding of the roofs of railway coaches in situ.

Copies of the Report may be obtained from the Anglo-American Council on Productivity, 21 Tothill Street, S.W.1., price 3s. 6d. post free.

PRODUCTIVITY IN GALVANIZING.

The report of the A.A.C.P. Specialist Team on American general galvanizing practice, which has just been published, will be of value primarily to galvanizers of miscellaneous general work and hollow-ware, but it also contains much information of interest to other galvanizers and to manufacturers of work to be galvanized. It is based on observations made in the autumn of 1950 during a tour sponsored by A.A.C.P. with E.C.A. technical assistance. Out of about 20 American galvanizing shops visited, some were engaged in general jobbing work for the trade and others were restricted to galvanizing the products of the firm of which they formed one department.

Supplies of zinc in the U.S. were becoming scarce when the Team arrived. Nevertheless, the Americans appeared to show little interest in the possibility of conserving supplies by measures to reduce ash or dross formation. In this respect British Galvanizers benefit from co-operative research which is almost non-existent in U.S.A.

The American Industry. Most of the shops seen were no larger than many in Britain, but the volume of work passing through them was much greater. Otherwise expressed, the Americans make more intensive use of their capital equipment. The number of men per galvanizing bath is greater than in Britain, and the quantity of work galvanized per man-hour, which is a measure of productivity, exceeds that in British works. This faster rate of working is due not to greater physical effort but partly to the way in which the labour force is deployed and partly to the care given to the design of handling equipment.

" Of importance is the thought which is given by management to ensure an even flow of work and to the handling facilities needed by each particular type of article. Physical effort is lightened as far as possible by mechanical aids and by reducing each job to the simplest degree attainable. This appears to result in a greater intensity or continuity of effort. The American worker is not apprehensive of mechanisation, but realises that his wages ultimately depend on the firm's prosperity, which in turn depends on its productivity."

" The quality of supervision is also of great importance. It is directed towards arranging the work so that every man is automatically kept fully employed, thus giving full scope to the will to work which is particularly evident in America." Supervisors are also encouraged to take part in technical conferences, and the Team recommends that similar opportunities should be afforded in Britain.

Galvanizing Shops and Equipment. The construction of the buildings and their lighting and ventilation are described. The ventilation is usually very good, owing to the ingenious use of hoods, extraction ducts and pedestal fans. The design of the galvanizing baths is generally fairly simple ; full details are given, with drawings. Oil fuel and natural gas oils are widely used for heating them, and some electric resistance-heated baths were seen. Information is also presented on the low-frequency induction-heated baths which are being tried out in one or two works.

All the shops visited were very well equipped with electric monorail hoists, running on straight lines, loops or elaborate tracks with several switch points. The Team recommends that " the maximum use should be made of travelling hoists of relatively light capacity (5-10 cwt) to eliminate heavy manual work." Related to this point is the further recommendation " The dipper should be continually fed with work, and where possible this should be done by means of a chute or conveyor. It is important that the dipping time should control the galvanizing process and that the dipper should not have to fetch work nor carry it away."

The Galvanizing Process. The main distinction between American and British galvanizing technique is the almost exclusive use of hot sulphuric acid for pickling in the U.S. Though it has technical advantages, and is, on the basis of acid equivalents, cheaper than hydrochloric acid, the latter is preferred in Britain because it does not need heating. One of the advantages of sulphuric acid, which is the possibility of recovery and regeneration, was not being applied by any firm visited, but there then appeared to be no shortage of acid supplies. This and other factors may encourage a greater preference for sulphuric acid in Britain.

Pickling is always followed by a water rinse and pre-fluxing, either in hydrochloric acid (in the older plants), or in a hot neutral flux solution. The advantages of a neutral flux are strongly emphasised. Drying ovens are hardly ever used, the work drying sufficiently in the air for it to be dipped safely through the thick flux layer which is maintained on the entry end of the galvanizing bath. All the work thus has to be passed under a weir, or else twice dipped. No dry galvanizing (i.e., without flux blanket) was seen. " In view of all that has been written in the American technical press about dry galvanizing, this discovery was very surprising." " The relative effect of the flux blanket in reducing zinc losses by oxidation as compared with the formation of flux skimmings containing zinc is a matter for further investigation.

Several of the firms visited paid a little extra to get their zinc delivered in bundles, some of the bottom slabs having feet to facilitate handling by a fork-lift truck. The slabs were held together with steel tape, and each bundle weighed about a ton. " At one plant it was said that 50,000 lbs. of zinc had been unloaded in 2 hours by one truckman and two assistants. If the ingots had not been palletized the job would have taken 5 or 6 men a full day."

As in Britain, most firms add small quantities of aluminium to the molten zinc. While some firms claim a reduction in pick-up, the majority are mainly concerned with improving the appearance of the coating, which was generally excellent. A simple device for making such additions is illustrated in the Report.

Dipping Technique. " The Team was very favourably impressed by the extensive use made everywhere of mechanical handling devices throughout the galvanizing process. Time and methods study engineers were employed in many galvanizing plants and given full scope to develop their ideas in order to obtain maximum productivity, and much ingenuity was displayed in designing racks, cradles, jigs, etc.

Whatever method of dipping was used, the quality of the galvanized coating was seen to depend very much on the method of withdrawal from the molten zinc. A smooth, uniform coating was only obtained when the withdrawal was slow and continuous, conditions which were well satisfied in some works.

Hot water cylinders and water heaters were seen being dipped individually, in batches, and automatically on a continuous conveyor.

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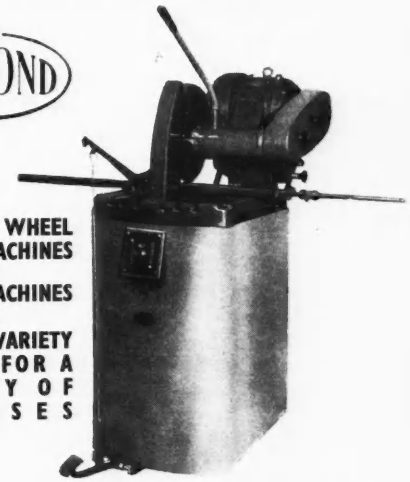

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One of the most interesting automatic plants seen used a continuous conveyor for dipping malleable cast iron elbows. The dipping cycle took 10 minutes, and the machine treated 160 tons of castings per week. A small section of the Team had an opportunity to see an automatic machine for galvanizing buckets which were however, dipped without hoops or bail handles. The machine was claimed to effect a valuable saving in labour, but those who saw it thought that considerable study would be required to construct a similar machine in Britain to deal satisfactorily with all kinds of light hollow-ware.

Residues. About half the firms seen were recovering zinc from zinc ash. The methods employed, which are simple and economical, are described. The recovery of zinc from dross was only being operated by one very large firm visited by the Team.

Costing. Some of the main costing methods are summarized, and the Team concludes that " more consideration should be given to the time factor in costing job galvanizing."

Zinc Economy. The Report contains details of a zinc economy incentive scheme used in a large hollow-ware galvanizing plant with a resultant 15 per cent saving in zinc.

Copies of the Report are obtainable from the Anglo-American Council on Productivity, 21 Tothill Street, London, S.W.1, price 3/3d. post free.

British Insulated Callender's Cables Ltd., announce that the address of their Dublin office is now 53 South William Street, Dublin, C.1. Tel. No. Dublin 78475.

Ferguson Pailin Ltd., Higher Openshaw, Manchester 11, have transferred their London office to Bush House, Aldwych, W.C.2. Tel. No. TEMple Bar 8711-12.

Foster Transformers & Switchgear Ltd., London, S.W.19, has found it impossible to deal at their Wimbledon factory with the greatly increased volume of orders. Arrangements have been made, therefore, to transfer production to the new factory of Crypton Equipment Ltd., at Bridgwater, Somerset, as reported on page 237 of our July issue. These arrangements concern only the Switchgear production of the Foster business and they will allow more space at the Wimbledon factory to deal with the demand for Foster Transformers, Voltage Regulators and specialised Test Equipment.

Northern Aluminium Co. Ltd., announce that as from October 1st, the address of their head office and London areas sales office will be : Bush House, Aldwych, W.C.2. Tel. No. TEMple Bar 8430.

Powell Duffryn Ltd., announce that the address of the Registered Office of the Company is now 19 Berkeley Street, London, W.1. Tel. No. GROsvenor 3801. The previous registered office at 40 Lime Street, London, E.C.3, will in future be the City office of the Company.

The First Electrical Engineers' Exhibition, organised by The Association of Supervising Electrical Engineers, will be held at the Royal Horticultural Hall, London, S.W.1, on March 28th and 29th, 1952. Electrical manufacturers are invited to apply for full particulars to the Exhibition Secretary, P. A. Thorogood, M.A.S.E.E., 35 Gibbs Green, Edgware, Middlesex.

The Gloucester Railway Carriage and Wagon Co. Ltd., Gloucester, have re-opened their London office, under the management of Mr. G. Embleton, at 1 Albemarle Street, Piccadilly, London, W.1. Tel. No. GROsvenor 8206.

BRITISH STANDARDS

(Copies of British Standards may be obtained from the British Standards Institution, 24, Victoria Street, London, S.W.1.)

Carbon Steel Castings for Surface Hardening (B.S. 1760 : 1951). The specification covers the requirements for carbon steel castings for surface hardening by a local heating and quenching process. Two grades are specified :—

Grade A is required to show a tensile strength of 40 ton/sq in. and a surface hardness after hardening of 550 DPN.

Grade B is required to show a tensile strength of 45 ton/sq in. and a surface hardness after hardening of 600 DPN.

The full chemical composition is specified for both grades. Inspection and testing are covered in detail and an appendix gives recommendations on the repair of castings by metal-arc welding. Price 2/-.

Glossary of Terms used in the Plastics Industry (B.S. 1755 : 1951). This is one of the documents in the series which is being prepared to cover glossaries of terms used in various industries, and it is hoped that it will provide for greater uniformity and precision in the use of terms.

The terms are grouped in Sections to cover :

Chemistry	Properties
Industrial applications	Moulding processes
Constituents	Other manufacturing processes.

The terms listed in these Sections are fully defined. Price 6/-.

Power-Driven Mobile Cranes. B.S. 1757 : 1951 deals with road wheel mounted and tracked power-driven mobile cranes of different types, including the full slewing, part slewing and non-slewing types which may be either fully mobile on their own wheels or tracks, or fully mobile and mounted on lorries. It also covers semi-mobile types and portable cranes.

Eight types of cranes are described, and a number of the terms used in connection with them are carefully defined.

A comprehensive clause deals with testing.

An appendix has been included dealing with stresses in struts, and this follows the general method of the application of the Perry-Robertson formula which has been adopted in other appropriate British Standards. Price 6/-.

Classified Advertisements.

The rate for all classified advertisements is 6d. per word ; in bold print 9d. per word ; minimum order 6s. Box number advertisements 1s. extra. Instructions together with remittance must be received not later than the 3rd of each month for advertisements to appear in the same month's issue.

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WANTED

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